

North American Network for Remote Sensing Park
Ecological Condition (NARSEC)

Satellite Remote Sensing for Monitoring and Reporting the Condition of National Parks



March 6-8, 2007, Hotel Santa Fe, Santa Fe, New Mexico

2007 Workshop Report



Table of Content

Figures.....	iii
Tables.....	iv
Appendices.....	v
Acronyms.....	vi
Executive Summary.....	viii
Acknowledgements.....	xi
1. Introduction and objectives.....	1
2. Workshop organization.....	1
3. Monitoring parks and protected areas: the challenge	3
3.1. National Parks Service.....	3
3.2. Parks Canada Agency	4
4. Theme 1: Land cover and changes.....	6
4.1. Presentations	6
4.2. Discussion.....	10
4.2.1. Readiness of methods	10
4.2.2. Barriers to wider use	12
4.2.3. Research and Development issues.....	15
4.3. Actions proposed by NARSEC 2007 Participants.....	18
5. Theme 2: Landscape Pattern.....	20
5.1. Presentations	20
5.2. Discussion.....	24
5.2.1. Readiness of methods and barriers	24
5.2.2. Research and Development issues.....	27
5.3. Actions proposed by NARSEC 2007 Participants.....	28
6. Theme 3: Biodiversity.....	30
6.1. Presentations	30
6.2. Discussion.....	33
6.2.1. Readiness of methods	33
6.2.2. Barriers to wider use	36
6.2.3. Research and Development issues.....	37
6.3. Actions proposed by NARSEC 2007 Participants.....	37
7. Theme 4: Thresholds and assessment points	39
7.1. Presentations	39
7.2. Discussion.....	40
8. Other issues.....	43
8.1. Climate change.....	43
8.2. Future NARSEC activities.....	43
9. Follow-on actions.....	47
10. References.....	49
11. Appendix.....	52
11.1. Agenda.....	52
11.2. Charge to breakout discussion groups	54

11.3. List of participants	57
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Figures

- Figure 1. Monitoring networks comprising the NPS Inventory and Monitoring Program (Gross, 2007a).
- Figure 2. An example of an Ecological Integrity Indicator within the PCA Ecological Integrity Monitoring and Reporting Program (McLennan et al., 2007a).
- Figure 3. An example of the definition of remote sensing – based monitoring goals within a NPS Monitoring Network (Kennedy et al., 2007).
- Figure 4. The Park Ecological Integrity Observing System (Park-EIOS) and the role of satellite-based land cover products (Fraser et al., 2007).
- Figure 5. Impact of regional land use changes on land surface properties (Goetz, 2007).
- Figure 6. Landsat TM- based data layers available from the Multi-Resolution Land Consortium (Homer, 2007a).
- Figure 7. An example of landscape pattern connectivity analysis for the Antietam National Battlefield using graph theory (Lookingbill et al., 2007).
- Figure 8. Landscape connectivity analysis using network metrics (Theobald, 2007).
- Figure 9. Fire hotspots (1999-2006) detected through the Rapid Fire Detection Program (Ressl, 2007).
- Figure 10. The FragCube concept. A specific interpretation of fragmentation is created for each cell (Quirouette and Zorn, 2007).
- Figure 11. Distribution of two species in Canada's Nahanni National Park, predicted using niche models (Kerr, 2007).
- Figure 12. National gap analysis strategy employed in a multi-institutional project in Mexico (Kolb, 2007).
- Figure 13. Temporal changes in the connectivity of wetlands near Whistler, British Columbia (Rothley and McBlane, 2007).
- Figure 14. Targets and thresholds for Ecological Integrity measures as employed in the PCA Ecological Integrity Monitoring and Reporting Program (McLennan et al., 2007b).

Tables

Table 1. Promising remote sensing technologies with applications to parks and protected areas.

Table 2. A comparison of landscape pattern characterization methods.

Table 3. Other landscape information that may be provided through remote sensing

Table 4. Basic strategies for monitoring species abundance.

Table 5. An overview of methods for biodiversity monitoring.

Appendices

11.1 Agenda

11.2 Charge to breakout discussion groups

Acronyms

AMUSE	Automated Multitemporal Updating through Signature Extension
ANP	Las Áreas Naturales Protegidas de México
AVHRR	Advanced Very High Resolution Radiometer
CCRS	Canadian Centre for Remote Sensing
CCRS	Canadian Centre for Remote Sensing
CONABIO	National Commission for the Knowledge and Use of Biodiversity, Mexico
CONANP	National Commission of Natural Protected Areas (Mexico)
DT	Decision Tree
EI	Ecological Integrity
EnMAP	Environmental Mapping and Analysis Program
EO	Earth Observation
ESA	European Space Agency
ESLI	Ecologically Scaled Landscape Index
ETM+	Enhanced Thematic Mapper + (Landsat)
GAM	Generalised additive model
GARP	Genetic Algorithms for Rule-set Production
GEOSS	Global Earth Observation System of Systems
GIS	Geographic Information System
GLM	Generalized Linear Regression
GPE	Greater Park Ecosystem
I&M	Inventory and Monitoring Program
InSAR	Interferometric Synthetic Aperture Radar
LAI	Leaf Area Index
LC	Land Cover
LDCM	Landsat Data Continuity Mission
LIDAR	Light Detection and Ranging
LVIS	Laser Vegetation Imaging Sensor
MARS	Multivariate Adaptive Regression Splines
MAXENT	Maximum Entropy
MERIS	Medium Resolution Imaging Spectrometer
MISR	Multangle Imaging SpectroRadiometer
MODIS	Moderate Resolution Imaging Spectroradiometer
MRLC	Multi-Resolution Land Consortium
NARSEC	North American Network for Remote Sensing Park Ecological Condition
NASA	National Aeronautics and Space Administration
NLCD	National Land Cover Data
NOAA	National Oceanic and Atmospheric Administration
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	Net Primary Productivity
NPS	National Park Service
OLI	Operational Land Imager
Park-EIOS	Park Ecological Integrity Observing System
PCA	Parks Canada Agency
POLDER	Polarization and Directionality of the Earth's Reflectances

RS	Remote Sensing
RT	Regression Tree
SAR	Synthetic Aperture Radar
SPOT	Systeme Probatoire d’Observation de la Terre
TM	Thematic Mapper (Landsat)
USGS	United States Geological Survey
VS	Vital Sign (in this report, synonymous with Ecological Indicator)
VSM	Vital Signs Monitoring
WiLC	Wildland Fire Leadership Council

Executive Summary

The North American Network for Remote Sensing Park Ecological Condition (NARSEC) was established in 2005 as a collaborative working group of the national park agencies of Canada (Parks Canada Agency, PCA) and the United States (National Park Service, NPS). The primary goals of the NARSEC are to promote and facilitate the use of remotely sensed data for monitoring and managing national parks and other protected areas in North America. Periodic working meetings have been used as a major vehicle for pursuing these goals.

After a successful meeting in 2005 and in recognition of the significant progress over the past two years, a second workshop was organized for March 2007 with the following objectives:

1. To review and evaluate methods based on Earth Observation (EO) that are presently being developed by NPS, PCA and their partners for monitoring land cover, landscape patterns, and biodiversity - including their suitability, readiness and best practices for use in different ecological conditions across North America.
2. To identify successes, challenges, and additional needs with respect to these methodologies, in particular regarding their performance, testing/evaluation, and/or operationalization.
3. To identify specific opportunities for addressing these needs through existing or new cooperative initiatives, both national and international.
4. To identify areas and mechanisms for increased collaboration among North American agencies and scientists.
5. To provide a forum for exchanging experience and ideas about the effective use of EO in ecological monitoring, management and reporting.

The agenda was structured around four major themes: monitoring land surface changes in parks, landscape pattern characterization, biodiversity monitoring, and desired condition for protected landscapes. In all cases, the focus was on the use of remote sensing technologies and associated aspects. The workshop consisted of invited presentations, discussions in breakout groups and in the plenary, and poster sessions tailored to each theme. The parallel breakout discussions addressed, as appropriate for individual themes: the readiness of existing methods, barriers to wider use of these methods, R&D needs and opportunities, and actions that should be taken to deal with these barriers or take advantage of the opportunities. In addition, individual participants were canvassed at the end of the meeting regarding the effectiveness of the NARSEC and priorities for the next period.

Results of the workshop are grouped in this report by theme. Following brief reviews of the presentations, issues raised in the breakout group discussions are stated, followed by actions suggested by the workshop participants. In addition to NARSEC future activities, climate change implications for monitoring parks and protected areas were also touched on throughout the workshop as an overarching issue and climate change issues are therefore addressed in a separate section. The many specific comments and suggestions may be summarized as follows:

Land surface change:

- The development of RS techniques for monitoring land surface changes has advanced significantly since 2005, with emphasis on standardization and automation of products describing surface conditions and changes over large areas. Land cover distribution and changes with time, fractions of impervious areas and of tree canopy cover, fire dynamics, and other applications have been implemented over large areas. Further work is required in more systematic error analysis, additional testing in a wider range of environments, and peer review of the methods intended for ongoing monitoring.
- Significant barriers were identified that hamper wider use of existing methods, and specific remedies have been proposed. These remedies include significant time and information exchanges between park managers and remote sensing experts.
- Several promising remote sensing technologies exist that offer the potential to provide new or improved information on land surface characteristics and changes; further research and applications development should be vigorously pursued.

Landscape pattern:

- Landscape patterns are easy to measure but hard to interpret. The most promising methods identified include ecologically scaled landscape indices, graph theory, and fragmentation metrics. These methods have different strengths and weaknesses, making particular approaches more advantageous under specific circumstances.
- Existing remotely sensed data and products may contribute to the measurement and interpretation of landscape patterns through identification of corridors for species of interest, characterizing the spatial context of parks within their ecoregions, comparing current conditions to historical and possible future landscape scenarios, and in other ways.
- New types of information derived from remotely sensed data have the potential to significantly improve quantification and analysis of landscape patterns. They include fractional (sub-pixel) land cover, canopy structure, surface temperature, and certain cover types such as wetlands.

Biodiversity:

- Since ‘biodiversity’ has various meanings, it is important to define those aspects that are relevant to parks and protected areas; focal species and species richness are of most interest at the present.
- Different approaches have been developed to model distributions of individual species or species assemblages. These developments are gradually maturing, converging on a more limited set of fairly robust techniques such as Maximum entropy, Multivariate adaptive regression splines, or Generalized linear regression.
- Remotely sensed data and products may support species habitat assessment in many ways, and they have been successfully used to underpin the development of niche models and graph theory models for some species. The availability of representative species’ presence (and sometimes absence) data continues to be a pre-requisite for achieving accurate and consistent model- based predictions.
- Remote sensing enables detection of environmental change in near-real-time, thus (with the use of models) predict shifts in species distribution.
- The perception that the spatial scales of information provided by remote sensing systems and those addressed by ecologists do not align with the scales required by ecologists continues to be a barrier to more widespread and systematic exploitation of remote sensing for species

distribution- related monitoring. Nevertheless, with the increasing availability of moderate-to-high resolution (~30m-1000m) monitoring tools capable of quantifying ecological parameters, the role for RS in species distribution-related monitoring will continue to increase.

Targets, thresholds and desired condition:

- Although the ‘threshold’ concept has been extensively studied in ecology, an emphasis on ‘assessment points’ (levels of ecological variables that trigger an evaluation of the need for action) is preferred in the context of park management. Various conceptual problems remain that require further work in defining theoretically sound and practically useful assessment points for specific ecoregions, parks, focal species, and other aspects of parks that are important from the park management perspective.
- It may not always be feasible to define ‘desired condition’, particularly where historical data are not available or the environmental circumstances are changing (e.g., climate change impacts, land use pressure). Thus, ways need to be found to identify assessment points using other criteria.
- The importance and value of remote sensing technology depends on the questions addressed and the ecological setting. It will thus also depend on the evolution of ecological and management concepts that underpin the targets, thresholds/ assessment points and desired condition. Nevertheless, because of the ability to detect specific changes in near- real time, remote sensing will increasingly play a central role in ecological monitoring.

In all thematic areas, further development and increased use of remote sensing technology in parks and protected areas must necessarily be founded upon close collaboration between remote sensing professionals, ecologists, and park specialists. Increased attention needs to be given to larger scale issues, such as land use pressures within greater park ecosystems and climate change impacts at regional to continental scales. Successful application of remote sensing technology to address specific protected area management information needs will also require incorporation of remote sensing expertise in protected area programs and associated budget support. Numerous specific suggestions for actions by the national agencies, the NARSEC, and the scientific community were made to achieve these results.

Acknowledgements

The breakout discussion sessions were moderated and reported on by a number of participants whose contribution to this report is gratefully acknowledged:

Section 4.: Gary Geller, Chantal Ouimet, Darren Pouliot, Scott Goetz, Robert Fraser, Y.Q. Wang, James Irons, Salman Rasheed, Stephen McCanny, Robert Bennetts.

Section 5.: Bruce Jones, Dan Kehler, Dave Theobald, Philip Lee.

Section 6.: John Wiens, James Rettie, Jeremy Kerr, Todd Lokingbill.

Section 7.: John Gross, Donald McLennan, Dan Kehler.

1. Introduction and objectives

The National Park Service (NPS) of the United States, Parks Canada Agency (PCA), and Mexico's National Commission for Natural Protected Areas (CONANP) are charged with protecting and restoring ecological values in diverse protected areas in their respective countries. Recognizing the critical importance of landscape dynamics in and around the protected areas, and the potential value of satellite earth observations (EO) for gathering environmental information, these agencies have agreed to sponsor a number of proof-of-concept projects over the past several years. These projects have focused on developing protocols to generate useful, cost-effective information on park landscape condition.

The initiative 'North American Network for Remote Sensing Park Ecological Condition' (NARSEC) was established in 2005 to promote and facilitate the use of remotely sensed data for monitoring and managing national parks and other protected areas in North America. As part of advancing the development of remote sensing (RS)- based monitoring procedures, NARSEC organized a meeting in 2005 (http://science.nature.nps.gov/im/monitor/narsec/narsec_meetings.htm). One of the decisions adopted at the meeting was to hold a workshop in 1-2 years. Because of the significant progress over the past two years, the agencies sponsoring NARSEC felt the timing was appropriate for evaluating existing products and current needs, and for charting a path forward.

The objectives of NARSEC 2007 were:

1. To review and evaluate EO-based methods presently being developed by NPS, PCA and their partners for monitoring land cover, landscape patterns, and biodiversity - including their suitability, readiness and best practices for use in different ecological conditions across North America.
2. To identify successes, challenges, and additional needs with respect to these methodologies, in particular regarding their performance, testing/evaluation, and/or operationalization.
3. To identify specific opportunities for addressing these needs through existing or new cooperative initiatives, both national and international.
4. To identify areas and mechanisms for increased collaboration among North American agencies and scientists.
5. To provide a forum for exchanging experience and ideas about the effective use of EO in ecological monitoring, management and reporting.

2. Workshop organization

A primary motivation behind NARSEC 2007 was to inform the development of national monitoring programs through utilization of the latest knowledge and experience regarding effective use of EO and related methods. To achieve this result and the objectives listed above, the workshop was organized around invited presentations (to set the scene and provide input into discussions) and structured breakout group discussions. In the latter, questions developed by the organizing committee were discussed and results recorded (refer to sections 4.2., 5.2., 6.2., and 7.2.).

Three main issues were identified as timely and relevant topics for the meeting:

1. RS for Monitoring Land Surface Change in Parks. This topic was chosen because the primary value of EO is its capability for providing frequent, spatially comprehensive information on the type and properties of land cover and its changes. This aspect is especially relevant to protected areas which are often inaccessible on the ground - because of their size, lack of surface access, costs, or combinations of these three factors.
2. Landscape Pattern and Biodiversity in Parks. Landscape pattern provides the link between the EO- derived land cover distribution and some ecologically relevant measures. Landscape pattern directly affects the suitability of the landscape for supporting a variety of species and other elements of biodiversity, and thus serves as the bridge between land cover and habitat assessment. Similarly, changes in land cover may be interpreted in terms of changing habitat suitability.
3. Desired Condition for Protected Landscapes - Setting Targets and Thresholds. Collectively, targets are desirable values for selected indicators that describe a management objective, such as a healthy ecosystem. The ultimate goal of monitoring parks and protected areas is to maintain the environmental health and take appropriate action if the condition reaches an undesirable state. In monitoring terms, 'undesirable' means that some of the observed indicators exceed a threshold established for that indicator. Management action is a way of trying to keep ecosystem indicators within a pre-specified range.

These three topics were used as the basis for individual sessions. In each session, several presentations were selected to set the scene for the discussion, both through explanations of key concepts and issues relevant to that topic and by presenting recent results from North American studies. The presentations were followed by a discussion, in which groups of about fifteen participants discussed a set of questions. A total of 5 parallel breakout groups addressed the three sets of questions for topic 1, and two sets for topic 2; topic three was discussed in the plenary (no individual breakout sessions). Appendix 1 contains the agenda for the meeting and the breakout group questions.

Discussions in each breakout group were guided by a Moderator and recorded by a Rapporteur (refer to section 10.). After being presented at the plenary for questions, clarifications and comments, the notes from the breakout groups were revised and used to prepare this report. Since multiple breakout groups discussed the same questions, it was a challenge to compile these outputs to produce a clear and consistent message. Each group also proposed specific actions, which are summarized in the respective sections (4.3., 5.3., 6.3.). Individual views of participants regarding future priorities are listed in section 8.2..

3. Monitoring parks and protected areas: the challenge

National parks and protected areas are subject to increasing pressures from many sources, including environmental pressures due to global climate change, globalization, shifting demographics, intensified land use, and continuing erosion of biodiversity (<http://www.georgewright.org/2007.html>). Effective management response to these trends requires timely, comprehensive, and accurate information, which has led national park agencies to establishing monitoring programs for parks and protected areas.

3.1. National Parks Service

The US National Parks Omnibus Management Act of 1998 (http://www.nps.gov/gis/data_standards/omnibus_management_act.html) directed the Secretary to “undertake a program of inventory and monitoring of National Park System resources to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources”. In consequence, the National Park Service has implemented a strategy designed to institutionalize natural resource inventory and monitoring on a programmatic basis throughout the agency. The national strategy consisted of a framework with three components: (1) completion of basic resource inventories upon which monitoring efforts can be based; (2) creation of experimental Prototype Monitoring Programs to evaluate alternative monitoring designs and strategies; and (3) implementation of operational monitoring of critical parameters (i.e. "vital signs") in all natural resource parks. Subsequently, most prototype monitoring programs have been integrated into Inventory and Monitoring (I&M) Networks.

The intent of park vital signs monitoring (VSM) is to track a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values (<http://science.nature.nps.gov/im/monitor/VitalSigns.cfm>). Monitoring is intended to support assessments of the efficacy of management and restoration efforts; to provide early warning of impending threats; to provide a basis for understanding and identifying meaningful change in natural systems characterized by complexity, variability, and surprises; and to enable reporting against performance goals (Gross, 2007a).

The elements and processes monitored are a subset of the total suite of natural resources that park managers are directed to preserve "unimpaired for the enjoyment of future generations," including water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes that act on those resources (NPS Organic Act, 1916; 16 U.S.C. 1). Thirty-two Inventory and Monitoring (I&M) Networks have been set up to implement vital signs monitoring across the more than 270 US park units that contain significant natural resources (Figure 1). This large program is being implemented in phases; the first 17 networks are fully implemented, while the monitoring program in the final two Networks should be funded in fiscal year 2008.

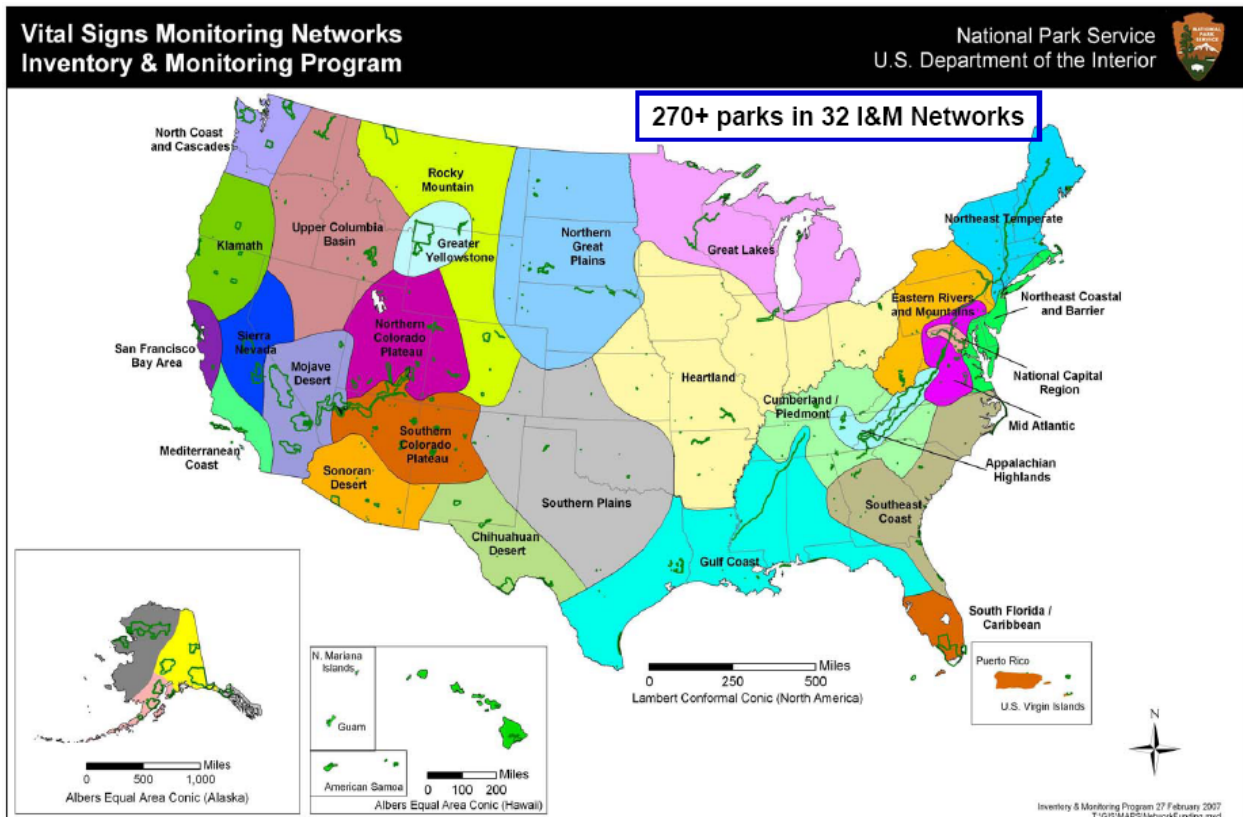


Figure 1. Monitoring networks comprising the NPS Inventory and Monitoring Program (Gross, 2007a).

The broadly-defined vital sign “Landscape Dynamics” has been the most commonly identified priority vital sign across the entire I&M Program (Gross, 2007a). Land use, forest pests, landscape condition, land cover, landscape pattern, primary productivity are among the indicators of landscape condition, each of which may be quantified through various measures (e.g., road density, housing density, impervious surface, structures, agriculture use, viewshed composition for land use). The recognized importance of landscape dynamics as a vital sign is an explicit acknowledgement that factors both inside and outside park boundaries have profound effects on park resources, in every region of the country (GAO 1994). The use of remotely sensed data will therefore be critical to the success of the I&M Program.

3.2. Parks Canada Agency

The newly-enacted Canada National Parks Act (2000) has sharpened the Agency’s focus on management accountability for the protection of ecological integrity (EI) in Canada’s national parks. Under the revised Act, the “maintenance or restoration of EI” is the “first priority” for all park management decisions (<http://laws.justice.gc.ca/en/>). This EI mandate is closely linked to the larger Agency mandate to provide for public education and memorable visitor experience, and further, that the success in protecting park EI depends in large part on our relations with partners, stakeholders, and visitors. This mandate interaction is particularly relevant to park

management issues involving landscapes contained within the greater park ecosystems of Canada's national parks (McLennan et al., 2007).

To provide data for increased accountability expectations, the PCA launched the National EI Monitoring and Reporting Program in 2003, where all national parks will develop improved EI monitoring and reporting systems by 2008 (PCA, 2005). Canada's 42 national parks have been working cooperatively within 6 bioregions under the guidance of bioregional monitoring ecologists to develop a most desirable set of EI Measures for 6-8 EI Indicators. For the most part the EI Indicators represent major park ecosystems such as lakes, streams, forests, wetlands, grasslands, tundra, shores and near-shore marine environments. EI Measures are the ecological factors assessed within EI Indicators. For example, EI Measures in park forests are sampled at a local (forest plot) scale [species composition, soil humus decay rate, stand structure changes, salamanders, songbirds] as well as at a regional (landscape) scale [e.g., landscape pattern, productivity, land cover change]. These various EI Measures are combined (Figure 2) to report on the EI condition of the Forest EI Indicator, and are reported in 5-year 'State of the Park' reports.

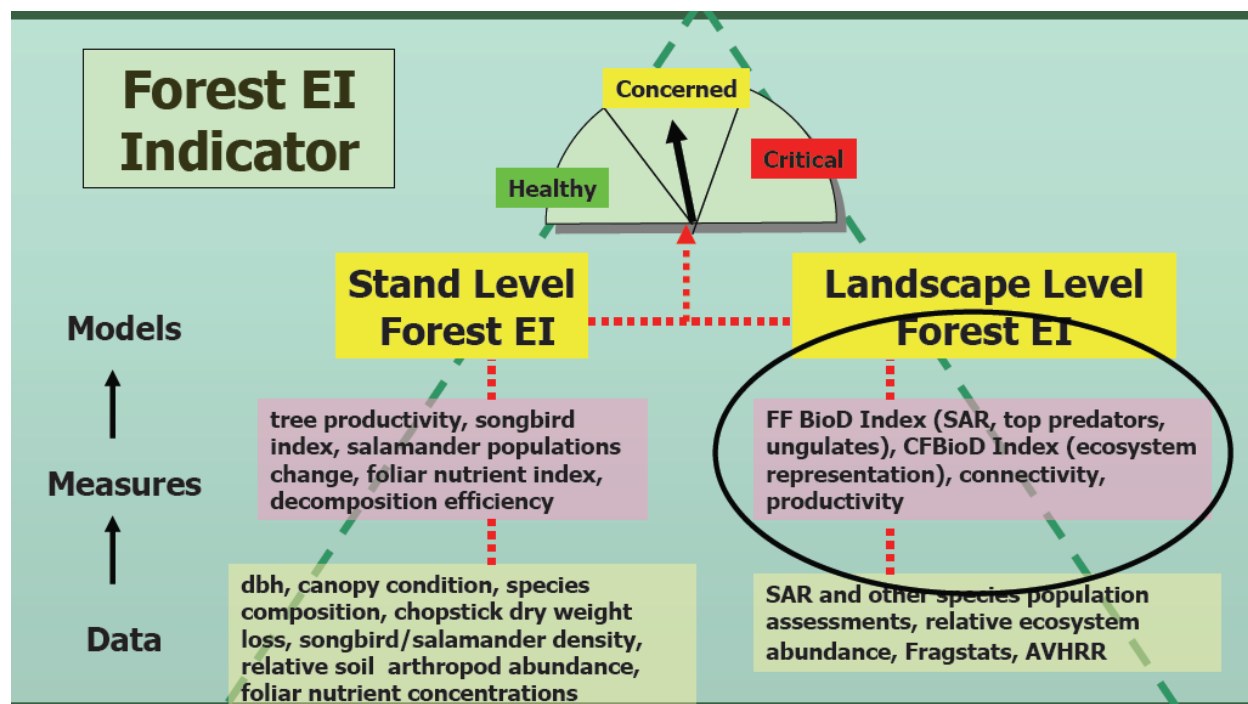


Figure 2. An example of an Ecological Integrity Indicator within the PCA Ecological Integrity Monitoring and Reporting Program (McLennan et al., 2007a).

Landscape scale EI Measures, to be derived from satellite and other remotely sensed data, are recognized as a very important component for long term EI monitoring in national parks of Canada (McLennan et al., 2007a; PCA, 2007). To acquire state-of-the-art methodologies, a collaborative project has been initiated to develop operational protocols for tracking changes in land cover, landscape pattern and biodiversity, and landscape productivity for the greater park ecosystem of Canada's national parks.

4. Theme 1: Land cover and changes

The status of the development of EO- based approaches for land cover and change monitoring in parks was assessed through three themes: readiness of methods recently under development for use in parks and protected areas; wider use of these methods and barriers to such use; and the R&D that should be undertaken to take advantage of new technologies and/ or to meet other priority needs. For each theme, a set of questions was prepared (section 11.2.).

4.1. Presentations

Several presentations were made to introduce the topics:

* Challenges in developing Landsat- based monitoring protocols in national parks (Kennedy et al., 2007):

In many ways, parks now need to push the bounds of traditional remote sensing change detection approaches: all resources must be tracked everywhere every year, using methods that can be carried out in-house, with minimal ancillary reference data for training and validation of RS products. The process of goal-setting and prioritization involves significant learning on the part of both remote sensing specialists and park scientists and managers. Diverse monitoring goals have to be placed in the context of fundamental remote sensing concepts such as spatial, spectral, and temporal grain and extent, often encouraging re-statement of monitoring goals in new ways more appropriate for remote sensing tools (Figure 3). This subtle re-framing of goals and needs could lead to solutions that address most needs in most places with reasonable cost.

Ecological monitoring goals of the NCCN Parks evaluated January 14th and May 13th, 2004, in Seattle, WA. All goals are characterized in terms of spatial and temporal grain. Based on spatial and temporal grain, as well as importance to the NCCN Parks, each goal was assigned a priority for consideration in the study plan. Those that are also likely to be achievable using Landsat-based satellite data are noted.						
Table 1.	Topic	Sub-topic	Spatial Grain	Temporal Grain	Priority	Achievable monitoring goal?
Alpine Vegetation		Bare ground impacts	1m	5 y	Skip (need higher resolution)	
		Interface w/forest	1m / 30m	Decadal	High/Advise	YES
		Vegetation Comm.	1m	> Annual	High	Advise
Forest Vegetation		Hardwood/Conifer	30m	> Annual	High	YES
		Forest Structure (classes)	1m / 30m	> Annual	High	YES
Disturbance		Vegetation disturbance in avalanche chutes	1m / 30m	5-10 yrs	High	YES
		Landslides	1m / 30m	Annual / > Annual	High	YES
		Fire	30m	Annual / > Annual	High	YES
		Insect/Disease	1m / 30m	Annual / > Annual	High	YES
		Windthrow	1m/ 30m	Annual / > Annual	High	YES
		Pollution	?	?	Low (important in future; impacts are not extensive enough to detect at present)	

Figure 3. An example of the definition of remote sensing – based monitoring goals within the NPS monitoring network (Kennedy et al., 2007).

*Land cover change protocol developed for Landsat in GRIP project (Fraser et al., 2007):
A Park Ecological Integrity Observing System (Park-EIOS, Figure 4) is being developed as an integral component of the overall park EI monitoring framework. It includes coarse filter EI measures corresponding to Landscape Pattern (i.e. PCA's FragCube), Succession and Retrogression, Net Primary Productivity, and Focal Species Distributions. A primary input to produce all four EI measures will be a time series of land cover and disturbance information derived from 30m Landsat TM and ETM+ imagery. An end-to-end change detection protocol was developed for Park-EIOS, dubbed Automated Multitemporal Updating through Signature Extension (AMUSE), and was demonstrated for two pilot parks using Landsat imagery from 1985-2005.

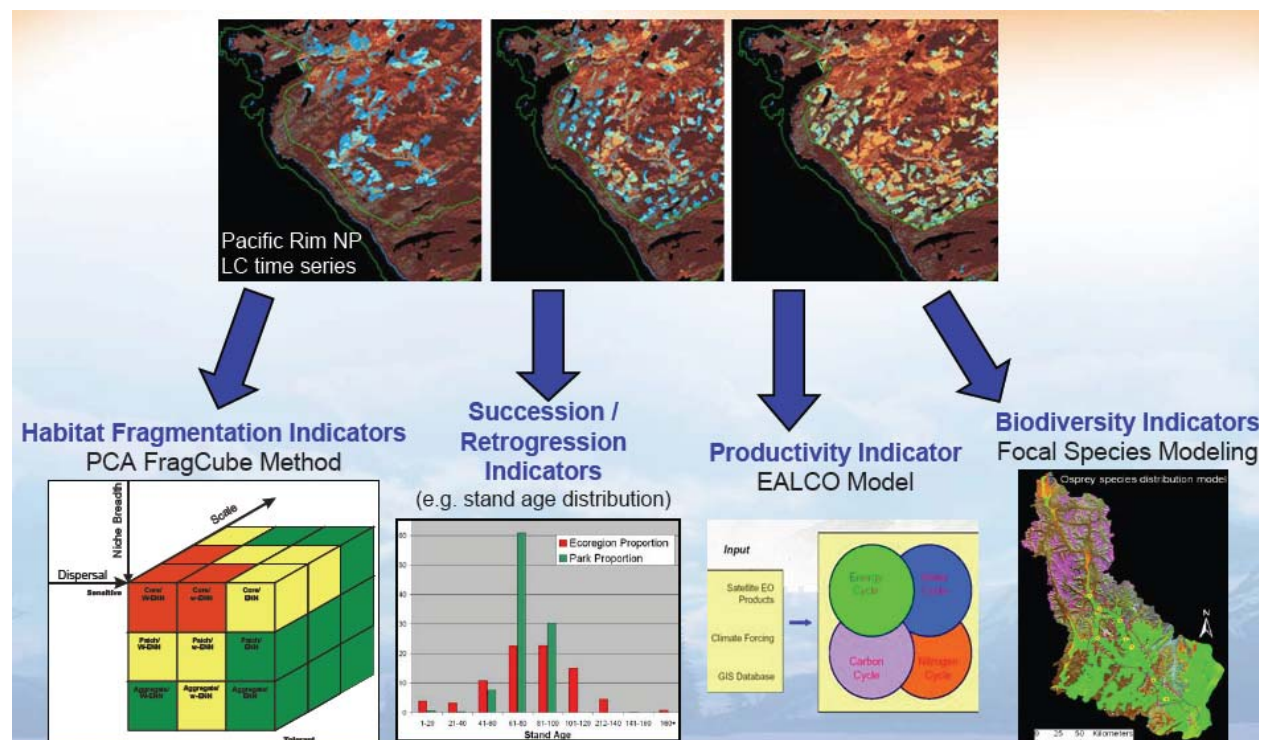


Figure 4. The Park Ecological Integrity Observing System (Park-EIOS) and the role of satellite-based land cover products (Fraser et al., 2007).

* Land cover change in the northeastern US and its effects on natural resources (Goetz, 2007):
Land management policies have been formulated in the Mid-Atlantic region and elsewhere to address the contemporary pattern of urbanization (low density, decentralized residential and commercial development) and to mitigate its impacts, but unintended consequences of the policies sometimes result. Satellite- based monitoring has tracked the expansion of dispersed development in Chesapeake Bay watershed and elsewhere in the region (e.g., Figure 5), along

with the impact on stream biota supported by field measurements. This information was used to calibrate models of the urbanization process that effectively capture the rate and pattern of change, predict expected development into the future under a suite of different policy scenarios, and to evaluate the vulnerability of natural resources in the region.

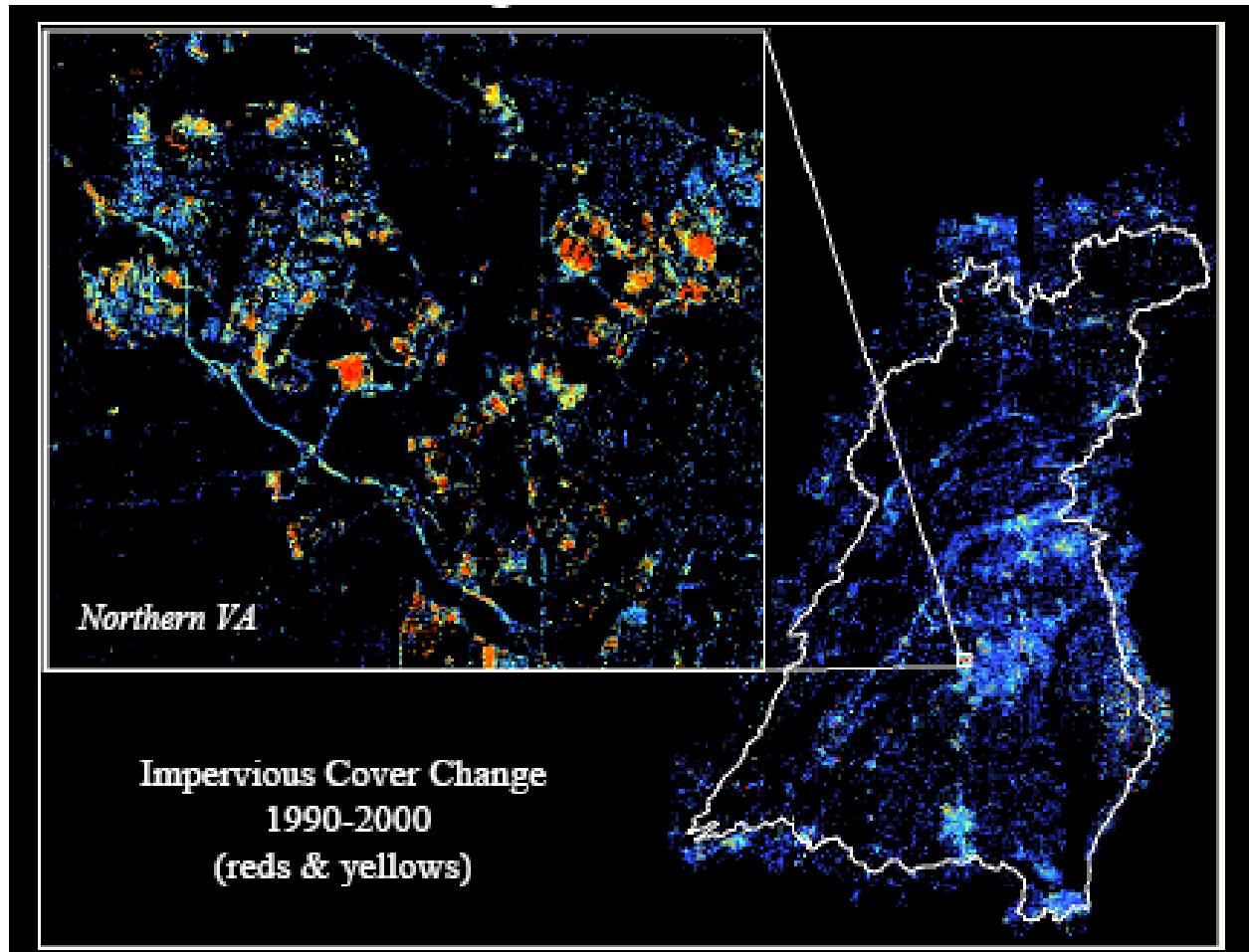


Figure 5. Impact of regional land use changes on land surface properties (Goetz, 2007).

* The MRLC land cover products and advances in detecting land cover change (Homer, 2007): The Multi-Resolution Land Consortium offers approximately 6,200 terrain corrected Landsat 5 and Landsat 7 ETM scenes (1982-2006). The recent completion of NLCD 2001 at 30 m resolution for the conterminous United States (Alaska, Hawaii and Puerto Rico are in progress) provides several independent data layers that can be directed at a wide variety of applications. Completed data layers include (Figure 6): (1) normalized Landsat TM and ETM+ imagery for three time periods per path/row; (2) elevation, slope, aspect, slope position, and other ancillary data; (3) per-pixel estimates of percent urban imperviousness and percent tree canopy, (4) a land cover product with 16 land cover classes and (5) and a product that identifies land-cover change

between 1992 and 2001. All MRLC imagery and NLCD data layers are available for download at www.mrlc.gov.

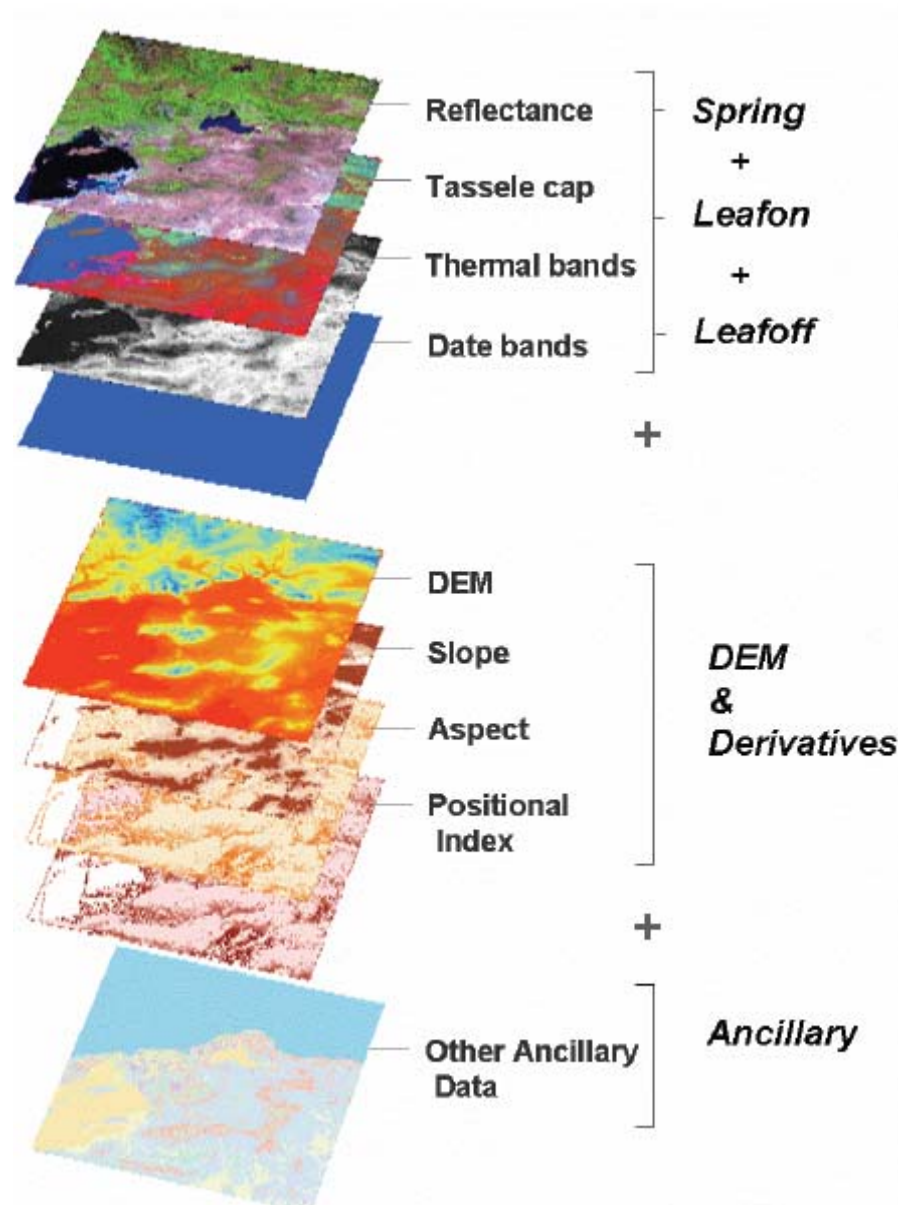


Figure 6. Landsat TM- based data layers available from the Multi-Resolution Land Consortium (Homer, 2007a).

* Status of the Landsat Data Continuity Mission (Irons, 2007):

Since December 2005, NASA has worked to implement a direction to launch a free-flyer LDCM satellite. NASA released a request for proposals for an Operational Land Imager (OLI) for the LDCM, a multispectral instrument capable of preserving the continuity of the Landsat data record in the visible, near infrared, and shortwave infrared portions of the spectrum. Selection of an OLI design is expected by June and will be followed by a request for offers to deliver the LDCM spacecraft for launch in July 2011. NASA also continues to consider options for placing

a thermal infrared sensor on the spacecraft although no decisions have been rendered at this time. Several activities are ongoing to mitigate the impact of the impending Landsat data gap and to prevent future reoccurrences, including the development of a Mid-Decadal Global Land Survey, studies by a Landsat Data Gap Study Team, and recommendations from a Future of Land Imaging - Interagency Working Group.

A summary of the discussion follows; proposed actions are listed in section 4.3..

4.2. Discussion

4.2.1. Readiness of methods

Discussion of the questions posed to the breakout groups (Appendix 11.2) yielded the following insights:

1. Information requirements by ecologists and park specialists:

- Methods that are appropriate for the spatial scales of the problem under consideration, ranging from high spatial resolution/ local (individual species) to moderate or coarse spatial resolution / global (ecosystems and biomes) – with corresponding temporal scales;
- Methods for detecting abrupt changes in land use outside the park (fire, insect epidemics); or gradual, cumulative, more subtle changes (succession, invasive species, climate change on freshwater or on vegetation);
- Methods that are transferable from one site to another;
- Archives of basic RS data to apply preferred algorithms or corrections;
- RS data that remain useful with technological change;
- Assurance that technological evolution does not change the ecological answers, especially between periods of observation;
- Rapid and early detection of areas where change occurred and for which more detailed information is required. This may be accomplished through the use of coarser resolution data which are available with high temporal frequency; fine scale data are not always needed.

2. A RS- based product may be considered ready when both the technological product and its applicability to a project /question (including park staff capacity and resources) are realized. A disconnect between development of products and users may result in products that are not useful (e.g., due to a spatial scale that is irrelevant to users), or it may prevent emergence of new products because of biologists' inability to articulate realistic information needs. Thus the development of useful RS- based products should be an iterative process founded upon a dialogue between EO and biologists or other park specialists, such as described by Kennedy et al. (2007).

3. Readiness of methods implies that:

- (i) The methods are appropriate to the spatial and temporal scales of the specific management objectives, and should be invariant with grain size (resolution):
 - Confine the boundaries of the problem (management issue)

- Ability to incorporate “ancillary data” (beyond post-hoc overlays)
 - Within-class variability is often of interest (e.g., canopy density)
 - Stratification can help focus on management issue (e.g., invasive species)
 - Vulnerability assessments require modeling as well as RS inputs.
- (ii) The algorithms are relatively insensitive to the source data (e.g., different sensors):
- Comparability of results across different types of sensors (e.g. multiple grain sizes)
 - Continuity between platforms is important
 - Comparability of techniques (e.g., NLCD).
- (iii) The approaches should be transparent in terms of being intuitive to the user and, if possible, relatively simple to use regardless of the level of algorithm complexity:
- Image data preprocessing (rectification, calibration, etc.) should be done by RS specialists (outside park agencies) to the extent possible because of the need for technical expertise and system capabilities
 - Some degree of automation in the algorithm interfaces is necessary
 - Amount and detail of “training data” required to run the algorithms is a consideration.
- (iv) The levels of uncertainty (error, precision) are attached to the outputs so that the user can have confidence in the results and understand how that relates to the problem of interest, particularly in terms of assessing threshold levels that might initiate management actions:
- Assessment of confidence in products is critical. Confidence in the RS- based products is built via participation in the process
 - The concept of accuracy in terms of the process of interest and relative importance of the RS product needs to be considered. Accuracy is important both in terms of *states* (LC, fragmentation, etc) and *rates* (change, trends)
 - In specifying the needed accuracy, it may be useful to work backwards from the question of interest, e.g. how accurate do the results need to be to make a management decision (or what tolerance for error is acceptable)? Also need to determine when accuracy / uncertainty a barrier to use. For management decisions, need sufficient accuracy to assess when changes exceed critical points.
 - The spatial accuracy of change estimates needs to improve; maps of uncertainty should be produced as part of the process.
 - In uncertainty analysis, accuracy is a broader concept than just ‘map accuracy’. Accuracy (as error, uncertainty estimates) should be carried through to higher end process models and incorporated into scenario analyses.
 - All of the above considerations require iterative interaction between information “producers” and “users”
- (v) The outputs need to be reconciled with previous trends and assessment results such that there is consistency through time. Improvements in techniques and levels of confidence in results can be applied to earlier timeframes / assessments, and currently established guidelines can be maintained.

4. Existing EO methodologies presented at the meeting:

- Three types of methods were presented at the meeting:
 - a. “Probability of Membership” (Kennedy et al., 2007): a fuzzy classification scheme which yields the probability (scale 0.0-1.0) that the entire pixel is covered by one of several cover types (shrub, conifer, deciduous, bare,...); change is determined as the difference in probabilities between two time periods;
 - b. AMUSE (Fraser et al., 2007) : based on radiometrically corrected, temporally consistent change images, change detection, and the labeling of detected changes as different cover types between periods; much of the process is automated, requiring only quality control;
 - c. Subpixel mapping / change identification (Goetz, 2007; Homer, 2007): using Decision tree (DT) and or Regression tree (RT) approaches (both supervised), and producing both land cover types (DT) and fractional products (fraction of impervious surfaces, fractional tree cover using RTs; changes in LC types are derived from overlaying t_2-t_1 change in fraction of impervious and fractional tree cover (per pixel).
- In general, strengths of a technique vary in relation to the context and the question to be answered. For example, while change vector methods may be more powerful than change detection, the former is a very complex method which requires ability to control errors; while change detection easier but needs to be optimized for individual situations, unless the procedure may be translated into decision rules. Change detection and vector analysis will not give the same answer, however they will provide the same direction of change.
- In any case, high geometric and radiometric fidelity of the RS data is critical, placing strong demands on the pre-processing methodologies which should be automated where possible.

4.2.2. Barriers to wider use

A number of methodologies and data products have been developed through research activities in many countries (including those discussed above), but their routine use in parks and protected areas remains limited. There are various barriers to a wider, more effective use. The identification of such barriers and possible remedies are discussed below.

1. Communication barriers

Numerous issues were identified under this heading. The above mentioned disconnect between ecological question/needs and the existing remote sensing products assumed to respond to these needs; lack of communication and coordination among different projects; lingering perception (in some cases) of remote sensing being oversold and unable to deliver on its promise; and lack of, and need for, effective communication between science and management in general (language barriers such as disciplinary jargon, scientists not having a good understanding of management needs and concerns, and managers not having a good grasp of the science and technology) all impede effective use of remotely sensed data. It is recognized that this barrier is not limited to remote sensing data, but applies to science and management generally.

Remote sensing technologies, specialists, and institutions produce a wide range of data and derived products for ecological purposes in search of applications that take advantage of the available technological capabilities. However, such remote sensing data and data products do

not necessarily address the needs of park managers or scientists for relevant information. On the other hand, park ecologists and managers do not always clearly describe their needs or compare their requirements with the capabilities of remote sensing technologies. Thus perhaps a key issue is the lack of effective two- way communication.

Part of the solution to the communication challenge is clear articulation of the needs for EO products and the intended uses, in relation to the management issues in parks and protected areas. Such a step requires higher level guidance through which the various agencies develop common vision and effective approaches. An example is the U.S. Wildland Fire Leadership Council (WiFLC; <http://www.fireplan.gov/leadership/about.html>), formed in response to the U.S. National Fire Plan. The WiFLC guided the definition and development of the remote sensing products and also provides multi-agency support and funding. A similar mechanism could be used to a) define standard, consistent remote sensing data products of greatest and widest use for park and protected area monitoring or for the broader scope of ecological monitoring across a range of scales; and then b) provide international and multi-agency support for the regular generation, validation, and improvement of the products. Such a mechanism would be most effective if governed by the guidance and direction of those working at local and regional scales, stimulated by international and multi-agency requirements for ecosystem monitoring within and beyond protected areas.

Other mechanisms that should increase awareness of RS capabilities and ecological applications include:

- Cross-disciplinary workshops / meetings: broadened communication across disciplines, to share experience on the process of how to get value from remote sensing - recognizing that effective communication mechanisms within disciplines may not be the best mechanisms to bridge the gap among disciplines;
- Designing and promoting solutions that address actual, recognized problems;
- Communicating to educational institutions the skill sets needed by successful applications to park or resources management, to help ensure that future practitioners have the necessary skill sets.

Regular meetings such as NARSEC 2007 are also a step in the right direction and should be encouraged, extended to other land management agencies, and supported by the community of stakeholders.

2. Lack of consistent higher level remote sensing data products

In general, higher level remote sensing products are not routinely and systematically generated from moderate (Landsat- type) and high resolution remote sensing data. This contrasts with the systematic generation of higher-level, global-scale data products that are routinely derived from coarser resolution (~250m and above) data. The lack of higher level products is a significant impediment because of the expertise and investment in the time and technology required to ortho-rectify, atmospherically correct, and radiometrically normalize moderate- resolution satellite optical data before they can be used for obtaining ecological information. Consequently, this lack seriously constrains the application of remote sensing to the inventory and monitoring of parks and protected areas.

To remedy the situation, there is a need to define and then systematically and routinely generate a suite of standard, consistent remote sensing data products for ecological monitoring. The leadership council suggested above could lead definition of a suite of products and set standards for formats, map projections, metadata, and documentation. At a minimum, ecologists should have easy access to affordable, ortho-rectified, atmospherically corrected, multispectral images of surface reflectance at local, regional, and continental scales because many ecologically relevant analyses of remote sensing observations require data processing to at least this level. Since the processing required to reach this level is extensive and presents a high overhead to ecologists looking to remote sensing for useful information, it can best be performed at facilities that implement the algorithms for high volume, routine data product production. - Beyond this stage, higher level products of broad utility could be produced by the same facilities, e.g. vegetation indices and other continuous fields (e.g., leaf area index, net primary productivity), thematic maps of land cover and land cover change, and surface temperature; the Multi-Resolution Land Characteristics (MRLC) data and the derived products (<http://www.mrlc.gov/>) are a useful prototype to consider for this process. However, the generation of the products need not be centralized, and could be distributed provided that the participating facilities adhere to the defined standards for consistent products. Coordinated processing would also alleviate the ‘timeliness problem’, when imagery scenes are out of date and/or when processing time extends beyond the time of critical information needs.

While standard products should meet a variety of common needs, ‘one size does not fit all’ and other needs will be park- or region- and problem- specific. Access to the source data and intermediate standard products used to derive the higher level products would help addressing this issue. Parks and ecologists would then be able to begin with the level of data product they prefer and tailor these as well as data types from other sources to fit their specific needs.

3. Incomplete or misleading representation of remote sensing capabilities and limitations

The inclination of RS specialists to ‘oversell’ remote sensing capabilities, dating back to early phases of remote sensing technology development, has created a barrier to the adoption of the technologies. In the context of parks and protected areas, much of the past remote sensing effort has been exploratory in nature, focused on the development of new methods and technologies rather on the establishment of proven techniques as an operational component of park monitoring and management. Ecologists and park managers can become quickly and deeply skeptical when promises of solutions through remote sensing are not realized and delivered. While research and advancement is necessary and beneficial, such results cannot be presented as proven outcomes when engaging ecologists and managers in the use of remote sensing data, in the areas where the research was done but especially in other geographic regions. - Another aspect of this issue is lack of technology awareness, especially understanding of the current technology and its capabilities which can lead to sub-optimal use, or misuse, of the data and derived products. Both barriers represent aspects of communications discussed above, and those proposed remedies should be effective in dealing with this problem as well.

4. Emphasis on mapping land cover instead of performance issues (e.g., ecosystem health).

The traditional preoccupation with thematic land cover mapping is becoming a barrier to a wider adoption of the RS data and technology by ecologists. While such information has been useful and will be needed in the future, increased emphasis needs to be placed on the development of

data products that more directly relate to the ecological condition. For example, the use of more frequent, multi-temporal observation of phenology at the landscape scale might prove more directly relevant to ecologists for protected area inventory and monitoring. Another example is fractional land cover products which provide more flexibility for ecological interpretation. Ecologists and remote sensing practitioners need to jointly identify relevant, useful data products which then need to be consistently and systematically produced.

4.2.3. Research and Development issues

Given the focus of the workshop on effective uses of existing methods, no presentations were made on experimental or future techniques. However, some posters addressed this topic, and the presence of people with the required expertise permitted addressing this issue from both ecological and remote sensing perspectives (refer to Appendix 11.2). The current remote sensing applications to parks and protected areas have benefited from technologies developed in the 1970s-1990s. They are capable of meeting various information needs, but by no means exhaust the potential contributions of remote sensing to the monitoring of these areas because of the specific technologies involved. Satellite remote sensing with different sensor designs (active, microwave, ..) offer new opportunities. In addition, previously developed techniques and products have not been sufficiently tested or used for purposes related to parks monitoring and management.

The most promising techniques and products are identified in Table 1. The strengths and weaknesses of each methodology and the ecological information it provides have been identified. It is evident that currently available methods capable of operational use have not been fully exploited, thus offering additional opportunities for park agencies to take advantage of in their monitoring programs. In addition, future R&D involving other sensors may be expected to significantly extend the type and quality of ecological information for use in the monitoring of parks and protected areas.

Table 1. Promising remote sensing technologies with applications to parks and protected areas.

<i>Method</i>	<i>Application / Information provided</i>	<i>Key strengths / benefits</i>	<i>Key limitations</i>	<i>Reference / Sources for more information</i>
High temporal frequency and moderate/coarse resolution (250m-1km) optical data (including geostationary platforms)	<ul style="list-style-type: none"> * Rapid response for large scale events * Continental scale burned area mapping * Ice and snow cover monitoring * Targeted acquisition of finer scale data * Study climate change effects, short term hydrological impacts, affect on snow, fire, visitor safety, monitoring vegetation phenology, others 	<ul style="list-style-type: none"> * MODIS/AVHRR (data timeliness) * Geostationary satellite data * Effective for large parks * Very inexpensive 	<ul style="list-style-type: none"> * Usually does not provide enough spatial detail on its own for EI monitoring and reporting 	NASA MODIS NOAA AVHRR SPOT VEGETATION ESA MERIS US NPOESS (upcoming)
Interferometric Synthetic Aperture Radar (InSAR)	<ul style="list-style-type: none"> * Biophysical measurements (biomass, vegetation height), wetlands mapping 	<ul style="list-style-type: none"> * Canopy penetration capability * Continuous, all-weather monitoring 	<ul style="list-style-type: none"> * Availability is a challenge (but RADARSAT2 in 2007) * Speed of instrumentation? 	www.radarsat2.info/
Hyperspectral	<ul style="list-style-type: none"> * Measure and monitor invasive species and vegetation under stress * Fractional vegetation mapping (within- pixel proportions) * Species type mapping * Fire monitoring and modeling (fuel load, water contents, fire propagation,...) * Can be used to monitor how density of species shifts 	<ul style="list-style-type: none"> * Continue mapping * Per pixel-classifiers vs. continuous classifiers * Percentage cover – sensitive to subtle within-class LC changes * More efficient than field investigation for large area mapping 	<ul style="list-style-type: none"> * Limited swath (7.5 km for Hyperion) – difficult to get large area coverage * Experienced analyst needed for data processing * Can be expensive * Continuity (lack of future operational sensors) * Some users (e.g. Parks) may not be able to handle the data 	NASA Hyperion (http://eo1.gsfc.nasa.gov/Technology/Hyperion.html) Airborne sensors EnMAP (Germany)
LIDAR and SAR active remote sensing	<ul style="list-style-type: none"> * Integration of LIDAR with optical RS data * Coastal monitoring (coastline, water depth, floating vegetation) * Vegetation structure 	<ul style="list-style-type: none"> * 3-D capability. * Many LIDAR data providers are available and the cost for data acquisition decreased dramatically * Quantifying vertical structure of habitat valuable 	Technology would probably be of secondary use to Parks after optical (e.g. Landsat)	NASA's Laser Vegetation Imaging Sensor, or "LVIS" (https://lvis.gsfc.nasa.gov/index.php) LIDAR: Northeast Coastal and Barrier Network (Fire Island, Cape Cod) have started using LIDAR data

		for ecological models		in coastal studies
Airborne sensors Digital aerial photos	Fine scale mapping and monitoring	Can be cost- effective	* Limited area coverage * Digital processing challenging	Digital mapping cameras
Fusion data products Integration of multisensor data and non remote sensing data	* Landscape dynamics * Long term monitoring * In climate change effects (long term), Short term, hydrological impacts, affect on snow, fire, visitor safety... monitoring dynamics of phenology * Arctic wetland monitoring (permafrost dynamics)	* Take advantages of different data strength * Maturing methodology * Acceptable resolution for the NPS land managers * Quantitative not just visual field investigations, even for small parks. * To address multi-scale questions	* Remote sensing can fill in for some of the aspects, good for large parks, may not effective for small parks. * RS is not the only tool for monitoring	
Fire monitoring and mapping	* Quantifying fire severity, detecting active fires, mapping burned areas, monitoring vegetation recovery	* Very cost effective and can cover large areas, especially when human resources are limited during major fire outbreaks	* Faster response time and more frequent observations required for active fire detection	* USGS/NPS/NASA: many past and on-going projects deal with fire science and data production * Operationally used in Canada (Fire M3 project) and Mexico (CONABIO)
Multi-angle sensors	* Quantifying atmospheric properties and canopy characteristics over large areas	* Distinguish different types of atmospheric particles (aerosols), cloud forms, and land surface cover attributes	* Data continuity uncertain	NASA MISR (http://www-misr.jpl.nasa.gov/) POLDER (http://smc.cnes.fr/POLDER/)

4.3. Actions proposed by NARSEC 2007 Participants

a) TO ENHANCE READINESS:

- Produce a User's Guide to help end users determine appropriate RS methods for their specific application (e.g., forest vegetation at 30m scale: can detect gross change in timberline, change in hardwood/ conifer mix using a variety of methods; cannot monitor specific species (e.g., old maple groves or change in mortality of trees). Also indicate:
 - levels of accuracy and the ease of use of various RS methods
 - which methods provide site-specific measures versus measures common to many landscapes
 - monitoring versus predictive methodologies
 - the applicability of methods with respect to specific questions
 - applicability of methods in two dimensions – spatial (species to ecoregions) and temporal (days to decadal).

The Guide could be complemented by a database of products already in use by parks, with information sufficient to support park personnel in identifying successful RS- based solutions that are applicable to their conditions.

- Consider developing a “strike team” that could be dispatched to parks or networks to help develop a specific land surface change solution. The jointly developed output would be a plan describing which products should be used for the monitoring applications.
- Consider a reference list of land use change experts who can provide advice, in an unbiased sense, on the applicability of given land use change approaches to specific management objectives in specific locales.
- Conduct focused comparisons of approaches at specific parks where change has been well documented and approaches can be validated / assessed for confidence, using the same pre-processed image data (e.g., NLCD).
- Test utilization of existing image data products at additional sites / parks to establish a core set of consistent baseline products that are available nationwide across all parks /networks.

b) TO ADDRESS BARRIERS:

- Establish an international and/ or inter-agency mechanism for developing consensus on requirements, products, and standards; and for initiating coordinated action (using the Wildland Fire Leadership Council as a possible model).
- Standardize RS products with different resolution/ grain size.
- Develop a data clearinghouse.
- Use NARSEC as a network for addressing common issues (e.g., within the Global Earth Observation System of Systems, GEOSS) and for promoting coordinated action.

- Endorse the National Land Imaging Program (e.g., through a letter of support) as an efficient approach to fulfilling mandated needs and a cost- effective use of RS technology.
- Develop process to facilitate RS integration into park/ resource management (e.g., through mentoring). Encourage more management involvement in workshops. Provide reporting summaries for park/ resource management in a problem- oriented style.
- NARSEC should consider a secretariat to coordinate interagency action on RS use; for developing/promoting presence at meetings, workshops, etc. in support of increased use of RS technologies; to promote action on RS technology development (e.g., new sensors); to improve accessibility and increase use of existing data products by park staff to support their spatial applications; and for other RS issues of common interest.

c) RESEARCH AND DSEVELOPMENT:

- High temporal frequency, coarse resolution data products are under-utilized tools for EI monitoring. They are valuable for rapid response for large scale events and to guide finer resolution data acquisition and analysis. Application fields include burned area mapping, ice and snow cover monitoring, targeted acquisition of finer scale data, study climate change effects, short term hydrological impacts, affect on snow, fire, visitor safety, monitoring dynamics of phenology. Park and protected area agencies should evaluate utility of these products, many of which (e.g., MODIS) are freely available for download.
- Fusing data products for integration of multisensor data and data products from different sources should be actively pursued by scientific community. It is a maturing method to study landscape dynamics, long term monitoring, climate change effects, short term hydrological impacts that affect on snow, fire, visitor safety, monitoring dynamics of phenology, and Arctic wetland monitoring (permafrost dynamics). Data fusion involving InSAR and other data products also has potential in many applications.
- More attention should be given to the use of LIDAR/hyperspectral technologies for invasive species monitoring and for quantifying habitat structure.
- Existing land cover and change algorithms should be used for case studies where changes crossed thresholds or that initiated management action (e.g., increasing watershed impervious cover exceeded a level where stream biota were affected and aquatic ecosystems degraded).
- Other RS- based land cover change techniques should be examined (e.g., Coppin et al., 2004).

5. Theme 2: Landscape Pattern

Landscapes are mosaics composed of interconnected or repeating land uses, and ecosystems, which result from the interplay of environmental/ physical constraints, disturbances, and biological processes (Bourgeron and Jensen, 1994). Landscape patterns are relevant to various environmental and ecological themes, including species distributions and abundance. Ecosystem functioning (succession, retrogression, connectivity) and stresses (land use) are reflected in the resulting landscape patterns. Landscape pattern measures are thus one of the means for linking landscape characteristics to the sustainable conservation of biodiversity values, a goal of managers and conservation planners (e.g., Vos et al., 2001). Because information about landscape patterns and their changes requires input data over large spatial and temporal domains, remote sensing technology is a well- suited monitoring tool.

5.1. Presentations

Three introductory presentations were made at the workshop:

* Evaluating landscape connectivity in an eastern US network of parks (Lookingbill et al., 2007): Small urban parks can play a vital role as biological refugia, migration rest stops, and dispersal corridors, all of which have been shown to greatly enhance regional biodiversity. The ability of parks to fulfill these functions is influenced by both landscape change within the parks and habitat loss and fragmentation in the surrounding environment. We are using a variety of remote sensing products and graph theory to evaluate impacts on local and long-distance connectivity for forest dwelling species (e.g., Figure 7). Two example applications are described: (i) identification of critical “source” and “pinchpoint” patches within a park for field monitoring of habitat quality; and (ii) an evaluation of whether a forest cut proposed to return a portion of the park to historic battlefield conditions would result in isolation of forest patches containing sensitive amphibian populations.

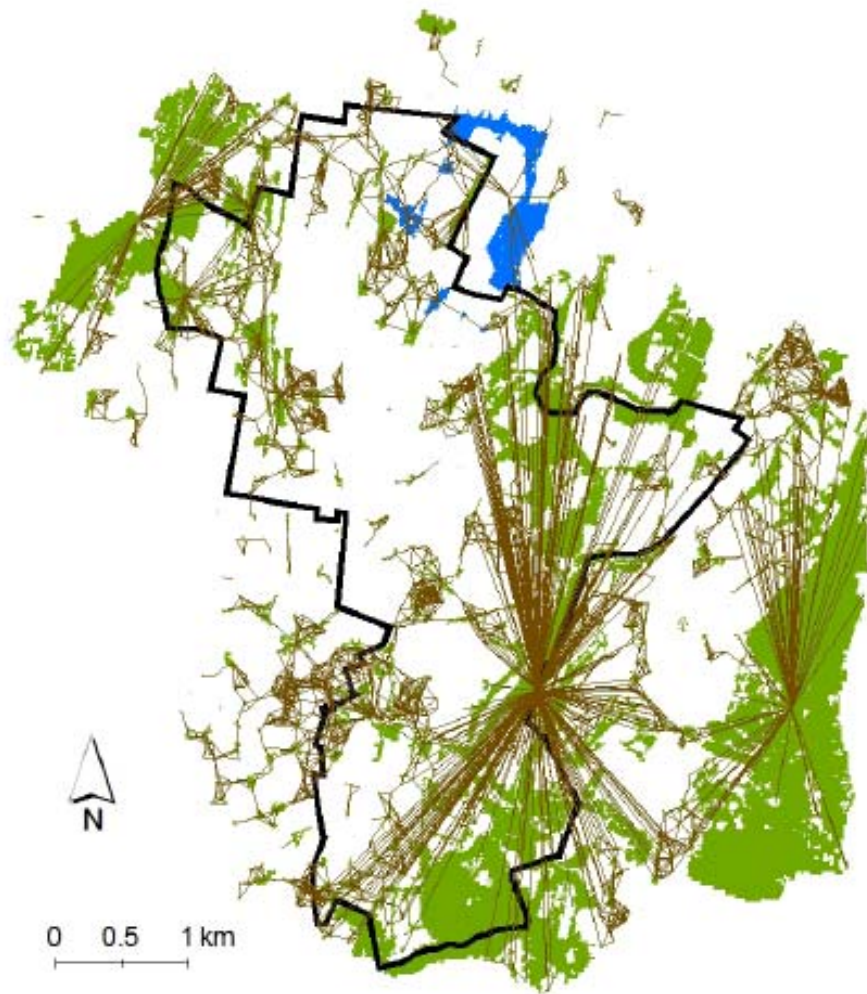


Figure 7. An example of landscape pattern connectivity analysis for the Antietam National Battlefield using graph theory (Lookingbill et al., 2007).

* Pattern metrics and significance of changes in land use and cover for park resources (Theobald, 2007)

Quantifying land use and land cover dynamics surrounding national parks has been identified as an important need by park managers and scientists. The dynamics of landscape composition, configuration, and connectivity around parks can be quantified using various metrics. These are useful to characterize the spatial context of different parks within their ecoregions, as well as to compare current conditions to historical and possible future landscape scenarios. They make it possible to find ways to place parks within the context of major processes – water, air, terrestrial, and human (e.g., Figure 8).

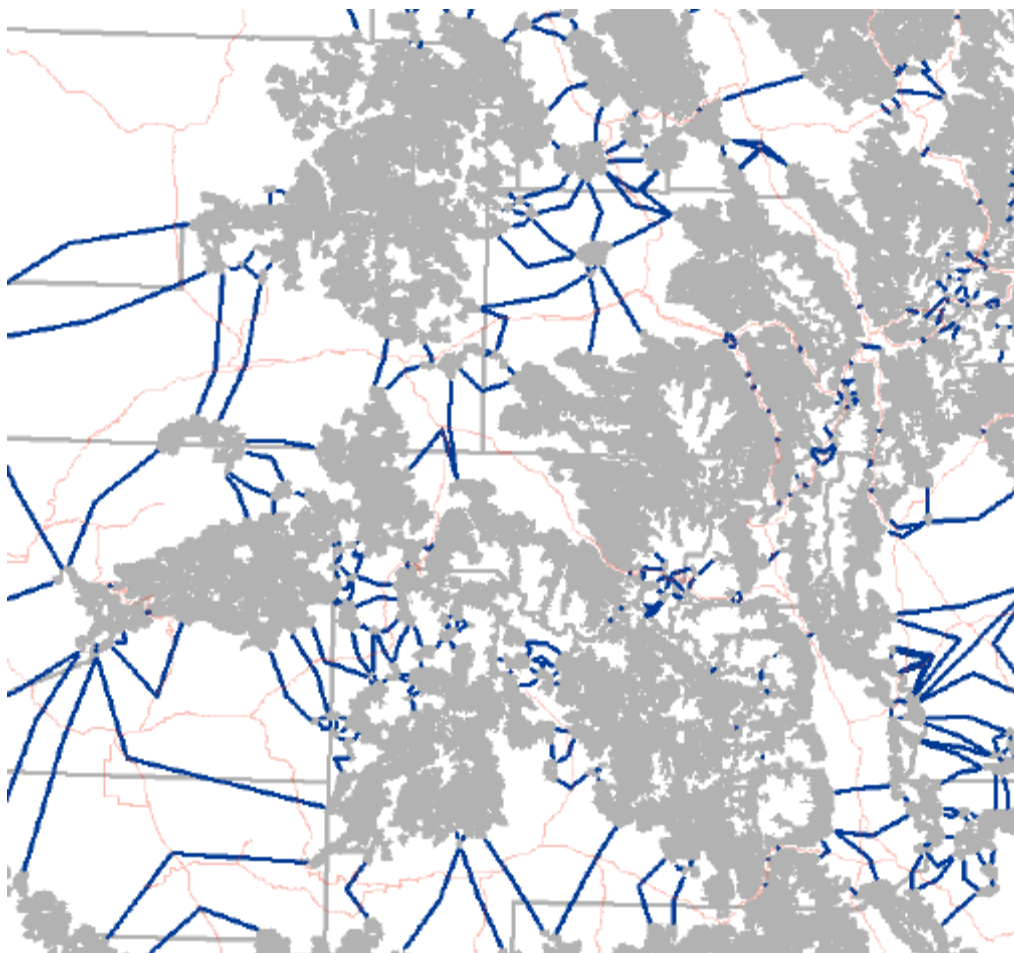


Figure 8. Landscape connectivity analysis depicting Canadian lynx habitat patches (grey) and movement linkages (blue lines); major highways are shown by red lines and county boundaries by grey lines (Theobald, 2007).

* Remote sensing based products applicable to National Park (ANP) monitoring in México (Ressl et al., 2007):

The National Commission for the Knowledge and Use of Biodiversity (CONABIO) in México has been operating the “Operational Program for the Detection of Hotspots Using Remote Sensing Techniques” since 1998. This program uses images from the Moderate Resolution Imaging Spectroradiometer (MODIS) on board of the Terra and Aqua satellites, which are received through the direct broadcast station at CONABIO, for the monitoring of near real-time forest fire events in Mexico and the Americas on a daily basis (Figure 9). In addition to the detection of active fires, the fires are classified according to their location with respect to vegetation type, accessibility, and risk to nature protection areas. A fire propagation/risk algorithm is currently being developed and tested using MODIS time series analysis and modelling techniques as part of the monitoring system. Our MODIS direct broadcast system is also used to develop an automated terrestrial product for land use change detection. One of the prime users of this product will be Mexican national parks (ANP), yielding multi-temporal remote sensing based information for continuous monitoring of land use and land cover change.

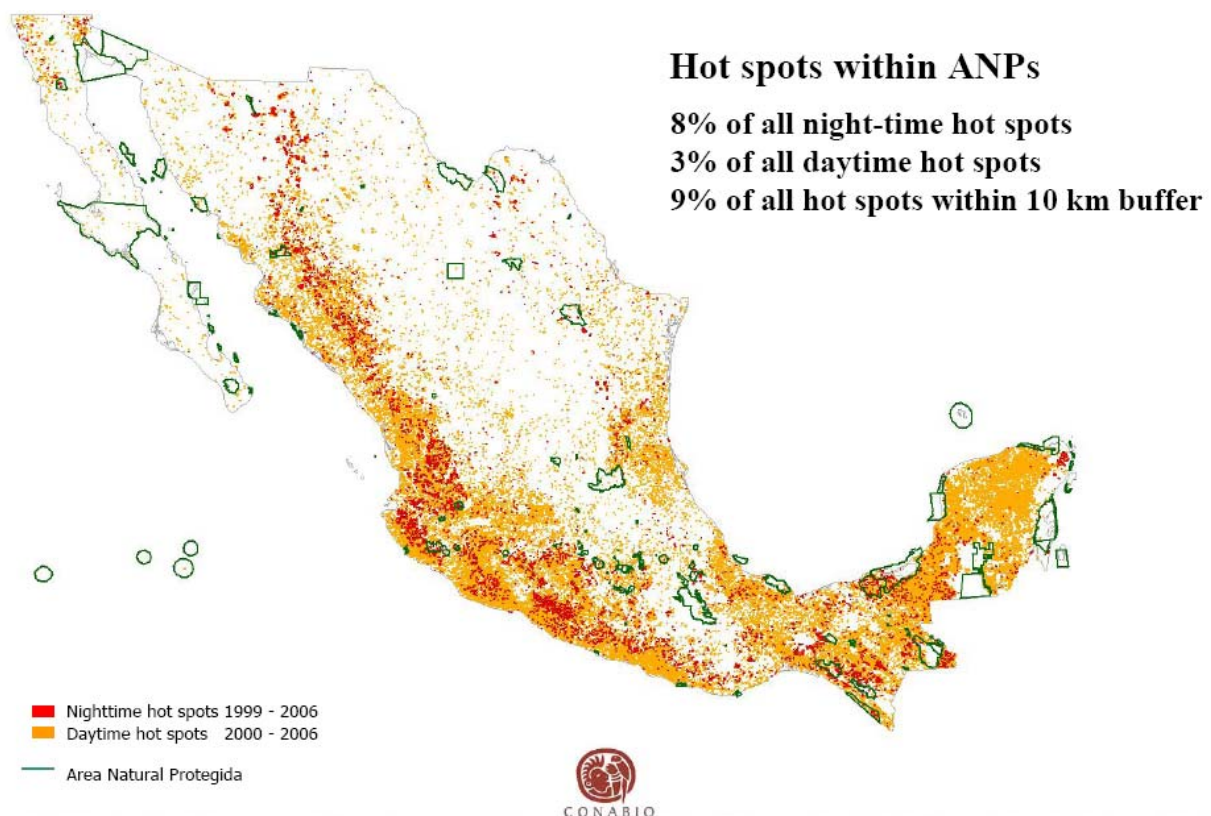


Figure 9. Fire hotspots (1999-2006) detected through the Rapid Fire Detection Program (Ressl, 2007).

* FragCube: An ecologically scaled landscape index for monitoring habitat area and landscape connectivity in Canada's national parks (Quirouette and Zorn, 2007):

A draft landscape pattern monitoring protocol has been developed for Parks Canada based on ecologically scaled landscape indices (ESLI). The procedure involves the creation of species profiles that target a range of species known to be relatively sensitive to relatively tolerant of landscape fragmentation. These profiles form the basis for ESLI's that represent "effective patch amount" and "effective patch connectivity" (Figure 10). Spatial and temporal patterns in these two metrics are assessed for monitoring. The ESLI approach is intended to complement other aspects of a park's monitoring program that include more focused, species-specific monitoring.

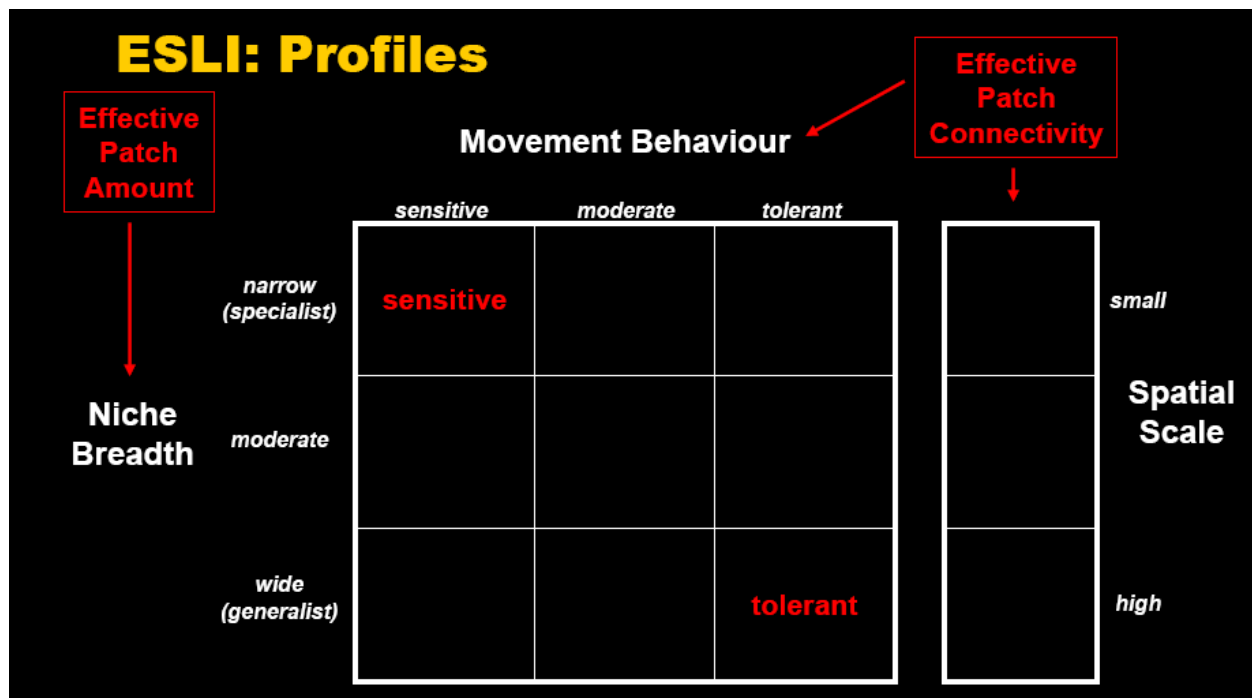


Figure 10. The FragCube concept. A specific interpretation of fragmentation is created for each cell (Quirouette and Zorn, 2007).

5.2. Discussion

5.2.1. Readiness of methods and barriers

1. Types of landscape pattern metrics

The following desirable properties of landscape pattern description methods and the resulting metrics were identified during the discussion:

- A generic approach but adaptable to individual species
- Relevant to multiple variables regarding a) species, b) processes
- Incorporating the matrix (barrier effects) – variability within the matrix
- behave in a predictable manner (monotonic, linear is ideal)
- Scale- independent (difficult for species- specific measures)
- Platform- independent
- Compatible with existing developments (e.g., Ritter's fragmentation metrics; Ritter et al., 1995)
- Work on natural and anthropogenic-derived fragmentation
- Spatial explicitness
- Needs to be able to be rolled-up
- Continuous rather than binary:
 - can account for differing uses of habitat
 - can account for gradients in the environment
- Easy to interpret (relevant to any monitoring metric; argues for functional approach); a) ecologically or physically relevant

- Easy to communicate (relevant to any monitoring metric)
- Easy to implement (relevant to any monitoring metric)
- High signal : noise ratio (relevant to any monitoring metric)

Four types of landscape pattern measures were discussed at the workshop, and their relative strengths and weaknesses identified (Table 2).

Table 2. A comparison of landscape pattern characterization methods.

Method	Strengths	Weaknesses
FragCube (Zorn and Quirouette, 2007)	<ul style="list-style-type: none"> • Facilitates working with complexity; profiles for different processes • It's a useful general tool that engages park ecologists • Transferable to different parks 	<ul style="list-style-type: none"> • Cost surface lacks standards • Complexity • Data and computing intensive • Not peer reviewed • Error sensitivity
Graph Theory (Lookingbill et al, 2007; Theobald, 2007)	<ul style="list-style-type: none"> • Includes the matrix • Output is visually intuitive • Flexibility in dispersal distances 	<ul style="list-style-type: none"> • Cost surface lacks standards • Complexity • Data and computing intensive • Error sensitivity
Fragmentation Metrics and multivariate composites (McGarigal and Marks, 1995)	<ul style="list-style-type: none"> • Well established • Easy to implement • Can capture a wide variety of pattern 	<ul style="list-style-type: none"> • Cost surface lacks standards • Complexity • Data and computing intensive • Difficult to interpret

Possible combined approaches include multi-scale integration of landscape pattern; and application of multiple methods (some may be better for exploration, others more robust). Other ways of quantifying landscape patterns include variogram analysis, methods that account for 3-D landscape structure, and methods that quantify linear features (roads, rivers). In general, the ESLI- type indices and graph theory approaches are preferable since they incorporate a degree of ecological understanding, compared to strictly computational techniques (e.g., FRAGSTATS).

2. Use of landscape metrics:

- Metrics are selected for: ecological relevance; management relevance; defining niche, movement, and scale for targeted species, guilds, or functional groups; maintenance of biodiversity, tracking impacts of disturbances, and supporting persistence ecological features.
- Patch definition is typically based on structural characteristics, but this may not be an ecologically relevant concept. Patches should define the type of use by a species, not just what can be mapped. Criteria are available to determine patches for species but there are special cases (migratory species, species dependent upon ephemeral features).

- Different categories of metrics: developed systems, e.g. % impervious surfaces, human accessibility. In natural systems, focus of metrics is on the patterns of the threats and stressors.
 - Multi-scale landscape analysis: focuses on hierarchical order of metrics, e.g. focal scale, controlling scale, propagating scale.
 - How to compare metrics from different landscapes? One possibility is to use a Monte Carlo method to derive a 'structured random' landscape and to compare the actual landscape to the 'random' landscape to determine significance of the differences.
- Landscape thresholds are difficult to establish. Their identification may begin by matching observational data and landscape pattern metrics; iterations will be required and will add to the confidence in the threshold.

3. Interpretation and use of landscape pattern metrics – “Landscape patterns are easy to measure but hard to interpret and use”:

- Linking metrics to processes: conceptual models are used to link metrics to account for interactions, their relationship to stressors, and thus to indicators. These connections provide ecological relevance. Iterations may be required before finding appropriate metrics.
 - While the landscape metrics are important for technical personnel, all groups are interested in the interpretation. Spatial analysis should help reveal the functional dynamics of the landscapes. Landscape ecology and conservation biology are ultimately linked to processes over the landscape. Landscape analysis focuses on hierarchical order of metrics, e.g. focal scale, controlling scale, propagating scale. Multi-scale, focal scale measurements may be used to make inferences about finer scales that may propagate up. Ecological relevance of landscape metrics is therefore of key importance.
 - Metrics emphasize patterns but there is the need to think about the dynamics and to linking with the dynamics through RS data. Incorporation of process into patterns is highly desirable but difficult because it focuses attention on single species, leading to a loss of generality (requires combining analyses for several species and rolling up the results).
- Understanding landscape structure. The concepts (e.g., patch definition, spatial resolution) are difficult to convey when communicating with managers and the public. How to make these relevant and to communicate them? The landscape pattern questions need to be restated and explained in management context. Ideally, landscape analysis should be structured so as to yield the information managers need. It is possible that the communications need to be tailored differently for managers and for public. Gradients are often transformed into classifications to make them easier to communicate but there are drawbacks, such as loss of information.
- How can progress in ecological management be assessed using landscape metrics? Need to start with essential ecological attributes within each category, identifying the important indicators, then selecting the most desirable subset based on practical considerations.
- Other ecological properties that may be addressed with landscape pattern metrics:
 - thermokarsts, failure of the permafrost, slumping events;
 - large processes such as climate change affecting large areas of the landscape;

- landscape diversity (through mean patch size).

4. Remote sensing data and products may contribute to the establishment of landscape pattern thresholds and targets, e.g. by:

- Comparing observations to published thresholds
- Defining graph theory rules
- Clearly communicate uncertainty (through metadata)
- Integrating across scales
- Remote sensing does not determine thresholds but it reflects the relationship and the reliability between RS and ecological response;
- It is possible to use historical data to identify a pre-disturbance state (e.g., historical air photos);
- Facilitates the gathering and handling of information.
- Methods that provide spatially explicit descriptions are preferable. Such methods should also benefit from new types of measurements, e.g. lidar and synthetic aperture radar (SAR) that area capable of providing information on the 3D canopy structure.
- RS may be used for model- based sampling, rather than relying on a probabilistic sampling design (e.g., Urban, 2002). Model- based sampling tests a hypothesis and makes assumptions about the structure of the indicator in the land base. Alternative: spatially balance design with some flexibility of adding samples, application of RS filters to determine appropriate areas of sampling. It is on the continuum from design and hypothesis based sampling. Provides greater flexibility.
- Guidelines for interpreting RS products should be included with RS data products (e.g., through metadata).
- RS- based products could be used for communicating park issues to the target audiences through, e.g.: 3D simulations, visualizations, hands-on experience; by presenting results on a local scale, connecting on a personal level; by enabling standard or consistent look and feel; by incorporating RS as regular part of business.

5.2.2. Research and Development issues

Items relevant to R&D emerged during the above discussion (section 5.1.) and are also reflected in the proposed actions (section 5.3.). In addition, other types of important information on landscape pattern were identified that might be obtained from satellite- based RS data. They are briefly described in Table 3 in terms of the need to be met, performance requirements, and the main challenges in meeting the need.

Table 3. Other landscape information that may be provided through remote sensing

Data Type	Need	Performance requirements	Challenges	Actions
Fractional cover	Better habitat description (ecotones)	Application specific; additional bands	Cost and accuracy; defining clear classes; validation	Cost sharing; developing methods for interannual change; developing standard vocabulary
Surface temperature	Solar Radiation	30m	Cost; Availability of	Addition of thermal

	Modeling		data, sensor	sensor to LDCM
Linear features (roads and streams)	Better habitat description; identification of fragmentation sources	Temporal resolution; consistency across political boundaries; higher spatial resolution	Technical challenges; data access; data volume; cost	Data access
Wetlands	Better habitat description	Higher spatial and temporal resolution	Different classification systems	Hybrid methods (optical, non-optical)
Disturbances	Better habitat description; identification of fragmentation sources	Higher spatial and temporal resolution	Cost; Capturing inter-class variation; forecasting ability	Research interclass variation; integrate disturbance as part of land cover classification at inter-annual scale
Canopy structure (lidar)	Better habitat description; fuel modeling		Data volume and availability; cost	Multi-agency coordination

5.3. Actions proposed by NARSEC 2007 Participants

- Education and training is required for biologists and resource managers. This is pre-requisite to a wider use of tools for landscape pattern analysis since people will only use methods they understand. Such action should/ could also include:
 - providing clear recommendations for software tools;
 - identifying important readings for landscape metrics, thresholds and assessment points, and applied publications for park management;
 - developing a primer on identifying thresholds and assessment points, e.g. reference conditions;
 - developing a catalogue of methods or techniques for specific RS- based monitoring metrics that are relevant to different ecological questions (including examples, validation, sensitivity biases, and testing of different ecosystems; some already exist) ; and of documented case studies and/ or working examples of where these methods have been used successfully, including the establishments of management targets;
 - developing or identifying workshops for other ecological/park professionals by landscape ecologists and RS specialists;
 - developing or identifying workshops for park managers by landscape ecologists and RS specialists;
- There is a need for rigorous testing and validation of the existing methods using in situ data to ensure the landscape pattern metrics are assessing what they purport to assess. Regarding functional approaches that rely on species (e.g., FragCube), sensitivity analyses are required to determine how well the species profile must be known.
- There is a need for the development of new methods/ software that will meet all or most of the above criteria, e.g.; single metrics relevant to multiple species; for a comparison of methods across difference regions; for the mapping of wetlands; and for the development of a

topology of conditions where RS will identify thresholds and assessment points, extending to conditions where it will only help find thresholds and assessment points.

- In view of the importance of thermal data for landscape modeling, a letter of support for adding thermal sensor to Landsat should be sent by NARSEC.

6. Theme 3: Biodiversity

In general, biodiversity ('biological diversity') refers to the variety and variability of all species of plants, animals and microorganisms, as well as the genetic resources that make them up and the ecosystems they compose. In workshop discussions, biodiversity was considered in the two meanings defined by Turner et al. (2003):

- in its organismal sense to refer to species and certain characteristics of species, in particular their distribution and number within a given area;
- in a broader sense to mean species assemblages and ecological communities, i.e. groups of interacting and interdependent species.

6.1. Presentations

The following papers set the stage for workshop discussions:

* State of the science for modeling focal species distributions using RS inputs (Kerr, 2007):

Maintenance of biodiversity is one of the defining objectives of park networks. Despite the importance of species conservation to the maintenance of parks' ecological integrity, poor data on species' distributions hinders effective management. This issue is particularly important in light of the essential roles required of parks to protect endangered species and safeguard native species against negative global change impacts. How can a small number of observations of where a species occur be turned into an operational model of the species' entire range? A number of niche modeling techniques now exist to facilitate the task of modeling potential distributions of species (e.g., Figure 11), and in some cases even communities. Many approaches have been tested quite extensively and the state of the art in this type of modeling is evolving rapidly. There are no hard and fast rules about what techniques necessarily perform best, although some in particular have proven reliable (e.g., Maximum Entropy). High accuracy data are necessary at every step of the multi-step processes that characterize niche modeling; however, accuracy testing is often poorly done. Despite their use with spatial data, running these models through time is essential for management but careful attention must be given to assumptions made in their use.

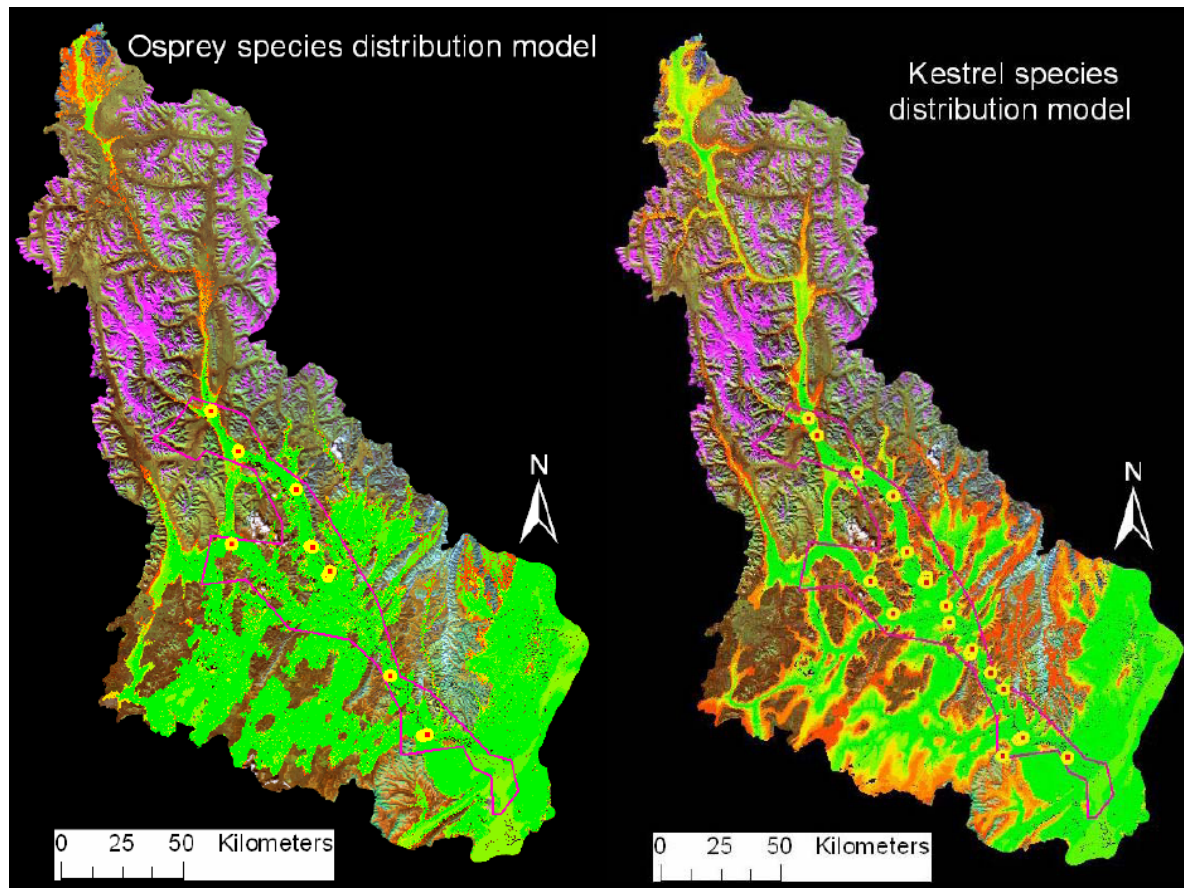


Figure 11. Distribution of two species in Canada's Nahanni National Park, predicted using niche models (Kerr, 2007).

* Multi-scale assessment of biodiversity in Mexico - new approaches to a national gap analysis (Kolb, 2007):

Numerous researchers and institutions in Mexico used a multiple-scale approach for gap analysis at a national level to detect priority areas for conservation, with scales ranging from ecoregions down to landscape level (Figure 12). The ecoregional approach is concerned with how well represented are the 75 terrestrial ecoregions of Mexico in the 405 natural protected areas. To determine terrestrial priority areas for conservation, several types of data were compiled, prioritization criteria were identified through workshops, and conservation hot spots and a possible conservation network were defined using a model (MARXAN). In case of coastal and oceanic environments, the priority areas for conservation were identified through an expert's workshop by selecting priority areas for taxonomic groups, and evaluating each site using biological and ecological criteria as well as major threats. The selected priority areas were then compared with the protected areas to identify the gaps. A web page (based on Wikipedia engine) was set up to facilitate a participatory peer review among specialists and as a tool for gathering relevant information.

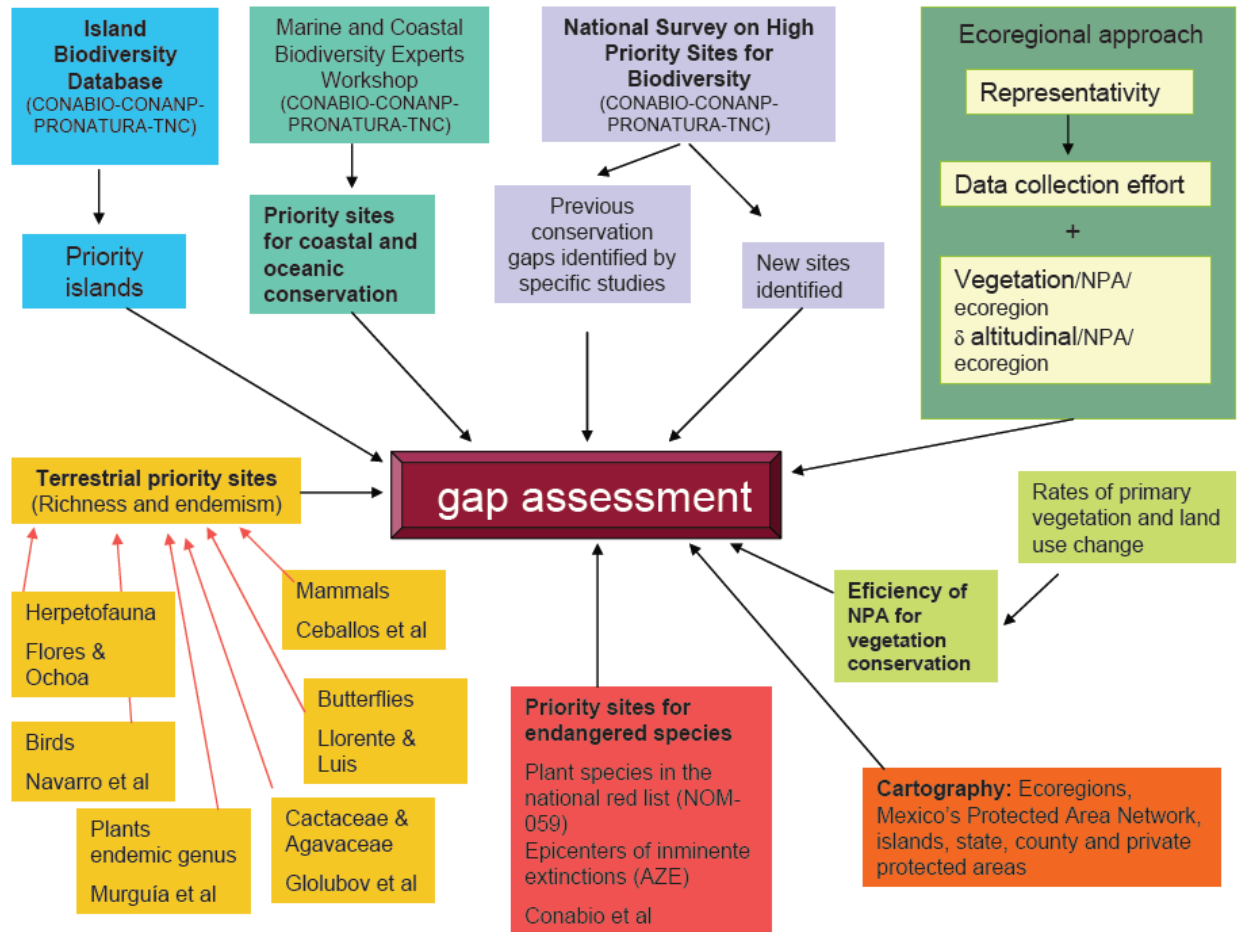


Figure 12. National gap analysis strategy employed in a multi-institutional project in Mexico (Kolb, 2007).

* Landscape-scale indicators of protected area quality and effectiveness (Rothley and McBlane, 2007):

The creation of protected areas is a common strategy for the conservation of biodiversity. Frequently, protected areas are delineated within landscapes that have been substantially disturbed through resource extraction, development, or both. In this study, aerial photographs were used to reconstruct the history of disturbance of wetlands in the Resort Municipality of Whistler, British Columbia. Graph-based metrics were employed to quantify change in connectivity over time and its differential effects on organisms with varying dispersal capabilities (Figure 13). We also used the aerial photos in pairs to determine whether changes (primarily losses) in connectivity were due to changes to the wetland patches themselves or due to changes in the traversability of the matrix between the patches.

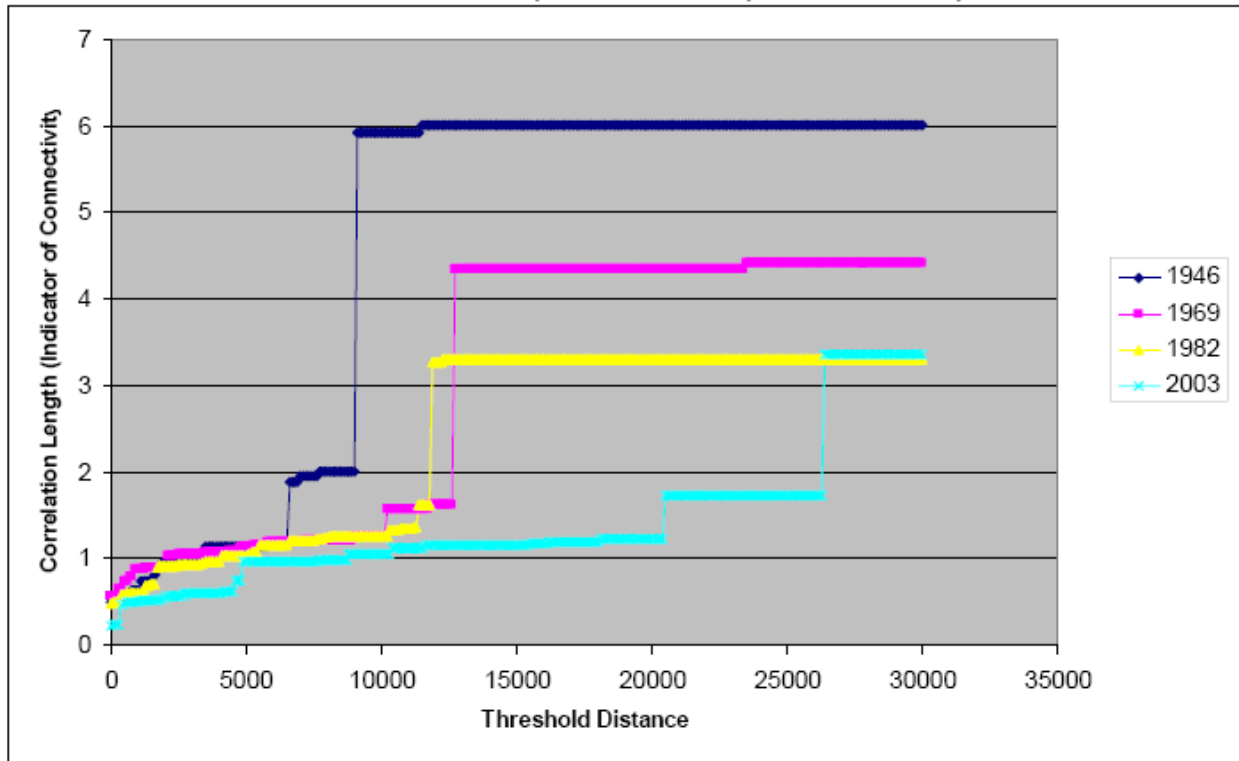


Figure 13. Temporal changes in the connectivity of wetlands near Whistler, British Columbia (Rothley and McBlane, 2007).

6.2. Discussion

6.2.1. Readiness of methods

1. Purpose of biodiversity monitoring

Biodiversity monitoring is important to parks and protected areas because of the need to:

- Conserve species in and around parks;
- Track change and processes that impinge on biodiversity within parks in some way.

Monitoring is needed because species assemblages evolve and species abundance tends to fluctuate within a natural range of variability.

In addition, biodiversity monitoring may be useful to track ecosystem functioning and services, although the latter are difficult to quantify.

2. Information requirements. What information about biodiversity is required within an area?

- Biodiversity has different meanings depending on the audience. The attributes being measured are either the targets unto themselves or they are surrogates for community, guild, or ecosystem health. In practice only a subset of the total community is monitored, not all aspects of the ecosystem. For individual species, the interest may be in species-at-risk, other individual species, species used as surrogates of biodiversity, species assemblages, community identification, others. Conservation biologists may naturally

consider species diversity. Others may consider persistence of target species or genetic diversity within populations.

- Parks and protected areas are often interested in monitoring (i) focal species (not biodiversity in general), or (ii) species richness (e.g. songbirds, vegetation). The first type requires life-history information; the second may not (Table 4).
- Other conservation agencies (e.g., The Nature Conservancy) use species richness in combination with ecosystem or community types to establish its conservation targets; this approach leads to answers about trends at various scales, without having to sample on the ground. Each of these will require a different approach and a specific spatial resolution.
- Some questions require only coarse level information, e.g. the probability that some species may occur in an area may be modeled with relatively low resolution satellite imagery as long as there is also accompanying finer resolution information about species presence (and ideally absence) in particular habitat types.
- Individual parks can have spatial models created to relate to specific conservation targets, to be used as decision tools to link scale to available information sources. The niche modeling approach appears to have the greatest potential, although the optimum method may vary with species and park conditions.

3. Existing methods

Table 4 illustrates two basic strategies for monitoring changes in species abundance or diversity, and Table 5 provides an overview of individual methods currently in use.

Table 4. Basic strategies for monitoring species abundance.

Basic strategy	Detail	Examples
Species by species approaches - fine filter: (focal species, e.g. endangered, keystone)	Life history (reproduction, mortality), presence/ absence monitoring	Population and habitat viability assessment models, in situ sampling
Ecosystem approaches – coarse filter	Tracks habitat and its change; uses land cover, LAI, impervious surface, disturbances	Species niche models are useful at this scale, assuming that adequate species location data exist

Table 5. An overview of methods for biodiversity monitoring.

Methods	Strengths	Weakness
Measurement - based		
In situ (camera systems, hair/fecal sampling)	Provides detailed (genetic, sex) information	Cannot get abundance directly, need an intensive sampling network for statistical estimates of abundance
High resolution satellite data (e.g., Quickbird)	Can provide abundance measurements	Restricted to large mammals in open areas
Lidar	Can provide 3D forest structure	Primarily for woody species; limited availability
Modeling - based		
Niche models	Spatially explicit range estimate from limited presence data	Sensitive to type and accuracy of input variables (cannot identify something as important if not in

	Good at refining patch definition Has potential to work on global scale	model) Cost surface lacks standards Complexity Data and computing- intensive Difficult to interpret, test and evaluate Only good for a limited number of species
Graph theory models	Readily scalable, use RS products to delineate and weight patches and matrix quality	Evaluating sensitivity for multi-species models is problematic

4. Species range (niche) models:

- Niche models use field sampling data of species presence (and sometimes absence) at particular locations and combine these data with environmental parameters characterizing the species habitat to model potential niche spaces, essentially environmentally-derived locations, for species of interest. Some of the environmental parameters can be derived through RS and used to project species distributions in space and time. For some species there is a good understanding of the species-niche relationship that enables making good use of RS. There is much information in the literature to assist in selecting attributes. The models are then functionally related to the RS measurements. Also, one can use this technique to identify key landscapes and habitats for persistence.
- Species distribution records can be valid methods to build relationships between species occurrence and environmental characteristics, but the value of such records also depends on the collection method.
- Many quantitative methods for modeling ranges are now available (bioclimatic models, GAP models, GARP, logistic regression, regression trees, GAMs, Maximum entropy , others)
- Niche models rely on biophysical data (including RS) to translate a small number of observations into synoptic range information (species occurrence)
- Model data requirements cover the major niche dimensions (i.e., environmental parameters or drivers) for the species in question.
- Niche models are strongly adversely affected by irregularities in the environmental data and by incomplete coverage of the environmental space.
- Recent work (Elith et al., 2006) indicates that GAM, GLM, MAXENT, MARS, and GARP models outperform other approaches, but their relative performance varies with species and input data.
- The reliability of model accuracy assessment is generally adversely affected by limitations of independent available data; the accuracy will not exceed the accuracy of inputs.
- Climate change may invalidate models through time, or their predictive power may change. Therefore niche (and other) models need to incorporate projections of climate change and its impacts. For example, predictions about climate change- induced vegetation change may lead to predictions about, a focal bird species. Then, we may need to consider the probability that habitat will be retained or to find other suitable habitat.
- All models need to be tested; while this may be met with resistance, it is critical for model development and reliable use.

5. Scale issues:

- Scale of analysis is an important component in all questions. Biodiversity issues span a range of scales and these place constraints on the use of various technologies.
- We need to have correct scale of information (temporal, spatial, etc.) appropriate to specific cases; these relate to the limiting factors. Finer grain data also provide more powerful predictors (e.g., temperature regimes). In contrast, sub-regional scale data are needed to target acquisition of new lands to be protected. Initial data may allow identification of other areas desirable to retain, or management actions designed to increase that habitat type.

6.2.2. Barriers to wider use

1. Use of remote sensing:

- In general, remote sensing can be used to support species habitat assessment in various ways:
 - Evaluate and monitor EI of parks within the surrounding context;
 - Guide in situ measurements. For example, initial spatial modeling may lead to additional sampling for improving the model, guided by RS products and resulting in a better link to RS data;
 - Measure effective (i.e., species- specific) patch statistics using FRAGSTATS-based metrics
 - Measure effective patch connectivity through graph metrics (sources, betweenness, correlation length)
 - Multi-scale approach: 1) start with remote sensing products (coarse scale), 2) supplement by in situ sampling to track changes in habitat (fine scale). Challenge is in linking information from remote sensing (e.g., disturbance) to field measures (e.g., species abundance).
 - Use RS products to develop species niche models which could be used as the input patches to graph theory models to guide in situ studies;
 - To identify/ track invasive terrestrial plant species, depending on the case (rate of invasion and rate of spread of invasion).
- RS data must be of high quality and consistent over broad areas; otherwise models for adjacent parks might have to rely on different data sources for the same species.
- Some RS data types can more directly measure the niche attributes for use in models, rather than building relationships and using surrogates.
- Due to the high cost of in situ monitoring and the consequent inability to monitor entire parks with sufficient temporal frequency, only RS data are likely to detect changes of biotic significance in time.
- Other approaches that should be explored to make effective use of RS-based data
 - Use of threat metrics, e.g. changes in population density, roads, disturbances
 - Vulnerability assessments
 - Evaluating trends and anomalies/inter-annual variability (climatic, land use development).

- Operationally, there is a need for a central clearinghouse to make RS data and products available and for the parks to have the tools available to them so they are able to make use of these. This will become more important as RS technology continues to develop.

2. Barriers and possible solutions

“The largest obstacle to applying these tools to both the scientific and conservation challenges before us are, for the first time, probably more cultural than technological. A perception problem continues to exist, even among those directly involved in developing and promoting remote sensing systems: the belief that the spatial scales provided by remote-sensing systems and those addressed by ecologists, evolutionary biologists and conservation biologists still do not match. This perception has probably prevented many otherwise interested and concerned remote-sensing researchers from pursuing the problems of greatest relevance to their colleagues in the biological sciences, and has kept most biologists from considering remote sensing as a useful tool. We believe it continues to do so today.” (Turner et al., 2003, p. 313).

The existing methods (section 6.2.1.) and RS capabilities for biodiversity- related applications offer a broader scope for applications than presently utilized in national parks. Steps towards removing barriers to a more widespread use were discussed and proposed actions are summarized in section 6.3..

6.2.3. Research and Development issues

Numerous topics and observations in sections 6.1. and 6.2. indicate the type and directions of future research that need to be pursued. In addition, the following specific suggestions were made:

- Development of higher resolution (+/- ~1m) or more complex RS measures, taking advantage of new technologies such as: LiDAR and InSAR for canopy structure; hyperspectral to identify functional types/groups and for specific invasive species monitoring; RapidEye or other rapid revisit/moderate resolution sensor, airborne sensors and data (refer also to Table 1).
- Building awareness of /comfort with RS tools/techniques and their potential contribution, through effective communications between park ecologists and remote sensing scientists and park managers.
- Development of tools to model threats to connectivity over time; e.g. housing density, expansion of impervious surfaces, fire frequency/intensity, spread of targeted invasive species.

6.3. Actions proposed by NARSEC 2007 Participants

The actions are grouped below by the suggested lead agent.

a) Individual parks

- Park superintendents/management should intensify monitoring parks' landscapes in broader, regional contexts, to reflect the continuity of land covers/habitats across park boundaries.
- Niche models and other tools (e.g., Population and Habitat Viability Assessments for well-studied crucial species) should be used more widely for quantitative assessment of the distributions/abundances of key species.
- *In situ* monitoring strategies need to be integrated across bioregionally similar parks, and all field measurements should be georeferenced to facilitate their use in model development.

b) National park agencies

- RS data should be used to provide connectivity and regional habitat context for constituent parks in network (see also section 6.1.).
- To ensure sustainability/biological integrity of individual parks, parks should not be regarded as islands but should include their GPEs and this should be reflected in park monitoring and assessments.
- Individual parks could serve as components (or nodes from graph theory perspective) in the broader regional framework of habitat protection, thus expanding the conservation potential of individual parks and the overall value of the national network.
- Park agencies should offer training to improve technical (GIS, RS) skills for park personnel, and to act as central clearinghouse for RS data and products where appropriate.

c) Satellite agencies

- There is a need for the provision of stable, basic, common RS data and products (e.g., land cover and changes (disturbance, phenology), biophysical properties (LAI, NPP or productivity surrogates), etc.. Data continuity and reliability are essential for any subsequent monitoring/modeling effort.

7. Theme 4: Thresholds and assessment points

For monitoring data to be widely used in a management context, there must be a scientifically defensible interpretation of the effects of change on resources of interest. While mechanistic conceptual models can articulate the interactions between key variables or functions, there remains a need to identify the point where some action is merited. The use of threshold values is well established in a regulatory monitoring context, and over the past few years ecological thresholds have received considerable attention and promotion as a basis for ecological monitoring and management programs. However, the evidence for thresholds or standards related to the composition, structure, and function of landscapes or biological communities remains elusive (Gross, 2007b), and the use of RS technology to establish thresholds has not been explored in a systematic way. The intent of this session was therefore to promote a dialogue that leads to effective uses of RS, not necessarily to undertake immediate actions in this area.

7.1. Presentations

* Increasing the relevance of monitoring data – thresholds and assessment points (Gross, 2007b):

The presentation reviewed conceptual models for thresholds, challenges to their use in the context of monitoring and management of protected areas, and an alternative approach based on management ‘triggers’ or ‘assessment points’. Effective assessment points should be:

Quantitative; Based on sound (some) documented science; Linked to scientific evaluation (e.g., ecological consequences); Identify potential mitigation/remediation actions, but the assessment needs to focus on science and explicitly avoid demands for specific actions.; Acknowledging the degree of uncertainty; and Contributing to an iterative process of refinement. Key challenges include:

- Many park resources are on the ‘pristine’ end of the ecological condition continuum but the emphasis in past work has been to identify thresholds related to human health or serious degradation. Many existing indicators may be insensitive to changes in systems that are nearly ‘pristine’;
- It is not clear how to integrate information about attributes that operate on different time and spatial scales;
- A need exists for a widely applicable, integrative, transparent, and management-relevant framework for the definition and use of assessment points.

* Developing ecological integrity monitoring targets and thresholds to define ‘desired condition’ of terrestrial landscapes in and around national parks (McLennan et al., 2007b).

To meet management objectives, the PCA defines a ‘greater park ecosystem’ that includes the protected area plus a surrounding area where land use and ecological condition directly determine our success in meeting management objectives inside protected areas (its extent may include the area required to maintain the genetic diversity of metapopulations of forest songbirds, species at risk or wide ranging predators, etc.). To be accountable to the public for the ecological condition of the park, an assessment of landscape condition is required (Figure 14). An approach widely put forward is that the present condition of the landscape be compared against a ‘desired landscape condition’. Targets for desired landscape patterns might be developed with reference to a) Pre-Columbian condition, b) Relative health and ecological integrity, or c) Park-specific management goals. The thresholds may be set by considering, as applicable: minimum

population size, balance of recruitment and mortality, minimum areal extent, or from information on distribution and stressors (to be obtained through monitoring).

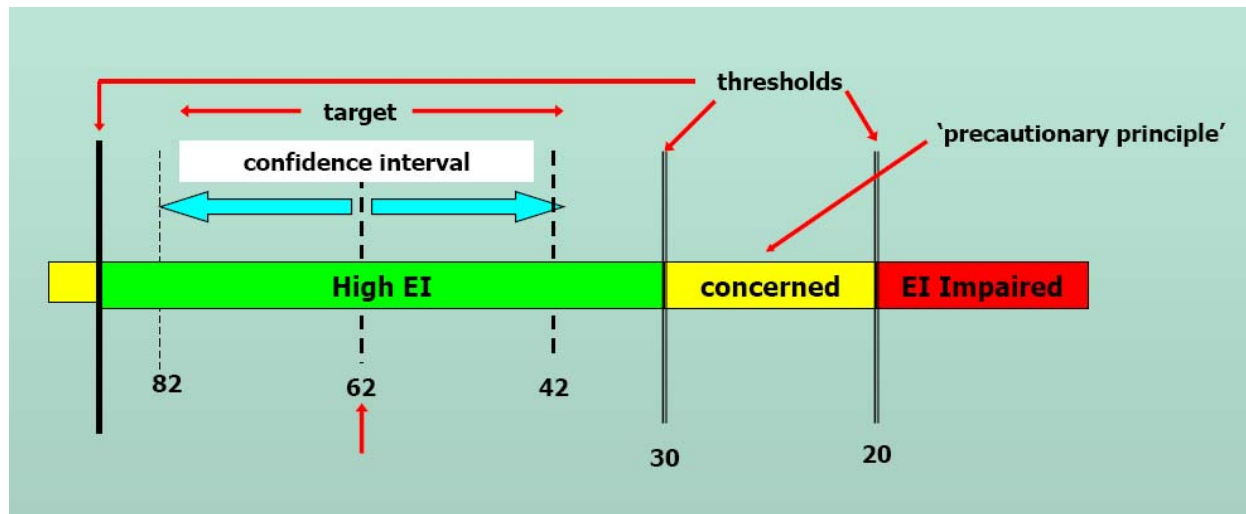


Figure 14. Targets and thresholds for Ecological Integrity measures as employed in the PCA Ecological Integrity Monitoring and Reporting Program (McLennan et al., 2007b).

7.2. Discussion

The following observations were made during the plenary discussion:

1. Thresholds/ assessment points:

- Calling thresholds ‘assessment points’ is useful, as it removes confusion about the function of thresholds (ecological vs. management) (Note: the term assessment points is used below to refer to represent either meaning in the park management context).
- Assessment points selected arbitrarily in the absence of other information (e.g., quartiles of statistical distribution) may be incorrect. Other options include:
 - Using a sliding scale (e.g., range of conditions); these values have more interpretability and the ecological significance may be more clearly evaluated. This approach would also provide a system for accumulating information for the future that could then be used to re-evaluate thresholds. However, the flexibility in interpretation may not always be welcomed by managers. In addition, how should the end points of the scale (for the sliding scale approach) be selected (e.g., if park condition is compared to that of a surrounding area, a park in central plains surrounded by corn fields would nearly always appear to be in good ecological condition)? One possibility is to consider only conditions in a subset of the bioregion/ecoregion that represent a potential desired condition for a park, and masking out other sections (using e.g. information provided through RS products) that are not relevant for determining desired park condition.
 - Using expert ecological knowledge, by generating ‘synthetic’ park landscapes that are represent plausibly good/ desirable and bad/ undesirable conditions. One

could then simulate changes to these landscapes, assess the effect on the metric of interest, and use this information to derive thresholds for the metric.

- The natural variability needs to be known before change can be assessed and assessment points identified. However, this may be difficult to achieve in a reliable way, as e.g. climate change may lead to future states that are outside the historical range of variation. Another option is to define desired and undesired states based on ecological knowledge, in the absence of a full knowledge of the range of natural variation.
- Assessment points should have a prescribed set of actions, but ecologists may not always be the best people to determine these. Crossing these points should set off alarms, and perhaps the first action should be to re-examine the set value of the assessment point. Next, an ecologist might consider what the issue is, and if it is well understood; if so, actions may follow naturally (e.g., communicating with partners in a meaningful way).
- Pre-Columbian condition is euro-centric and insensitive to the ecological effects of native peoples (who may be associated with mass extinctions and other large- scale ecosystem modifications). It may be an artificial reference that does not yield useful thresholds.

2. Role of remote sensing:

- Utility of RS for thresholds may be obvious in limited cases, such as observing encroachment. They may or may not yield ecological thresholds. Two examples are:
 - Fraction of impervious surface in stream catchment;
 - Processes that become self-propagating – positive feedback cycles (e.g. semi-arid systems where bare ground can self-propagate).
- A lot of the information required for setting assessment points cannot be observed through RS. Often, once these thresholds are crossed, it is too late to act. There is a need to catch irreversible changes before they happen. However, it should be possible to track movement towards a threshold and act before it is crossed, or to use precautionary thresholds.
- With RS- based intra-annual monitoring we could identify the changes earlier, but would require getting the RS data in timely manner.
- In RS land cover applications, assigning classification type constrains full RS use – therefore should move towards fractional, continuous descriptions.
- Simpler approach to RS: Initially can we just look for anomalies (changes between times) before going through the classification exercise. For example, use low resolution RS products first, before digging deeper (e.g., Yosemite fire shows high correlation between burn history and burn scores). This is conceptually similar to PCA's standard deviation-based threshold approach (PCA, 2007).
- How can RS help set up the reference condition? In the PCA approach (PCA, 2007), there is both an assessment of status and change relative to a baseline condition. How do we set that baseline/reference condition? One option is to use RS data to establish characteristics of the ecoregion a park is assumed to represent, and to interpret the status and trends in a park with respect to this reference.
- High temporal resolution RS data have 20-25 year time series. If we remove seasonality and look at anomalies we can identify the year of disturbance events occur, and their persistence through time (e.g., fires vs. impervious surface). We can generate maps of anomalies which we can then investigate in detail; this is done fairly routinely.

- It is a mistake to generalize what RS is most useful; the guidance should be provided by the ecological questions asked. To assess patch size, one needs a thematic, classified map. If interested in groundwater runoff, continuous data product is required. There is no just one tool for all jobs. This confirms the importance of the process of iterative consultation between the two communities.
- Relationships to hydrology, erosion, runoff and RS data have been studied well, and this knowledge should be taken advantage of.
- There are current methods to look at blending MODIS and Landsat data to start looking at intra-annual change – this is a very promising development.
- Need to examine the delivery model for RS products to parks.

3. Supporting management response:

- The motivation for this work is to help managers. We should keep in mind that threshold diagrams don't represent mechanistic relationships. If we see a clear correlation between two variables (roads and connectivity) that we might use to set a threshold, there isn't necessarily a causal relationship.
- If we are leading a restoration program, the assessment points for restoration will be different than the ones set after the restoration is complete. Degradation points do not necessarily equate to restoration points. Important message: the history of a site will be important in setting assessment points
- Does it matter whether the change is natural or not? The end result may be the same. We may have targets for species that need certain connectivity, and the cause of fragmentation may not matter. What is the state of the landscape, and what are my needs from the landscape?
- In the iceberg/assessment model, there is also the need to provide managers with options/recommendation resulting from crossing/reaching assessment points. Does it not take ecologists to advise managers of what the consequences of management actions are likely to be? Example: in Manassas National Battlefield, we want to restore battlefield by removing trees, we can provide consequences for e.g. to salamander populations.
- Assessment points are currently being done independently for each monitoring metric, but many metrics are related, and maybe we need to look at them as a complex.

8. Other issues

8.1. *Climate change*

Climate change emerged as a topic relevant to all workshop themes. The points made included the following:

- Parks provide an important base of information and an excellent setting to track impacts of climate change on ecosystems because parks tend to be less impacted by other simultaneous changes (e.g., land use and land cover alterations). Some measures can be taken system-wide, e.g. using RS products to develop continental assessments of climate change impacts. In addition, parks have an important educational role and they can communicate impacts of climate change to visitors.
- Although parks may have different perspectives on climate change, NARSEC represents a considerable diversity, thus providing a context for understanding how climate change affects the a variety of systems.
- Climate change will sometimes lead to a rapidly shifting baseline: will current thresholds become irrelevant? We can expect increased frequency and intensity of disturbance events. Therefore need to focus not just on long-term trends, but also on short-term dynamics. Frequently acquired RS data will be critically important in this context (e.g., to map onset of snowpack/ice on lakes, seasonal phenology, fire/ insect disturbances).

In this context, workshop participants commented favourably on the proposed North American Land Change Monitoring System (Homer, 2007b). This project, still in formative stages, aims to initially generate a variety of RS-based products at various spatial and temporal resolutions, ranging from 250m/10 day products across North America to 30m products at multi-year intervals. The products are to be sufficiently flexible to be useful to a variety of clients, simple and understandable, and able to meet multiple needs at multiple resolutions. The ultimate goal of the project is a dynamic land cover change monitoring system, updated on an annual basis and be a critical sustainable information source for users of land cover change products across the continent.

8.2. *Future NARSEC activities*

A questionnaire was distributed to obtain feedback on the workshop and the participants' views regarding future activities. Responses to two questions are summarized below (as written, with minimal editing).

PRIORITIES FOR THE NEXT THREE YEARS – suggestions:

a) More widespread use of RS

- Get something done.. real results. real thresholds (reference response measures) distributions for x,y,z
- Get to concrete action points
- Implementation of RS products into Inventory & Monitoring

b) Enhanced dissemination of RS techniques and products

- Catalogue/ library of methods and their relationship to ecological questions
- Development of a catalogue of methods/ approaches
- Further dissemination of data products and availability of resources

c) Further development of RS techniques and approaches

- Address accuracy issues (i.e. how to compute), + assessment points
- Breakthroughs with management applications
- Definition of uncertainty in RS data products
- Enhance cross- border testing/ evaluation of methods
- Exploration of a wider array of RS sensors
- Identifying assessment points for their ecological problems
- Let park priorities drive the RS tools and not the other way round
- Pushing science to develop better methods for monitoring RS
- Seek thematic connections across regions and national boundaries to address important common issues - climate change, disturbance regimes, focal species
- Solutions for RS processing, information translation to managers at park and network levels

d) Cooperation

- Consolidating cooperation across the whole region
- Continental efforts
- Encourage cross-border collaboration
- Interagency cooperation
- Joint pilot projects
- Stronger integration of Mexico
- Tri-country initiatives and global change perspective

e) Communication

- Bring together the community
- Communication
- Continue/ facilitate communication between NPS & Parks Canada
- Continued communication and collaboration
- Web site similar to the one in Mexico, using the Wikipedia engine
- Working on the communication issues (between RS applications, ecologists, managers)

f) Facilitating education about RS potential and use

- Bringing back more case studies
- Change detection review - case study
- Communicating the importance of RS to park resource management.
- Encourage GIS experience/ training @ all parks (easy!)
- Promoting the "best" metrics (and methods) for describing landscape change (patterns)

g) Advocacy

- Letter from NARSEC asking for addition of TIRS on the new LCDM platform
- Providing input/ guidance to North American RS activities
- Work with USGS & NASA to get data costs down (free Landsat) and to encourage the expansion of pre-processed image products

TOPICS AND TIMING FOR THE NEXT NARSEC MEETING – suggestions (as written, with minimal editing; not all respondents specified a date or topics):

a) Increased use of RS products and techniques

- Accomplishments since last meeting that came about as a result of this current meeting
- Climate change
- Common data sets; Common protocols; Advice on threshold setting
- Continental gap analysis - or at least methods to support it
- Delivery model - efficient processing and timely delivery to parks
- Delivery of end products
- Develop good case studies and communicate these well
- Development of RS to Actionable Management process
- Direct applications/ pilot applications
- Focus on building confidence & experience in use of RS within networks
- How to increase communication between RS and parks
- Models for processing, information from setting objectives, collecting information, interpreting information to making meaningful to parks
- N. American monitoring framework definition
- Priorities as identified from park community
- Sharing experience
- Sharing models
- Sharing failures/ setbacks
- Showcasing good examples stories of successful applications to management/ monitoring questions
- Usefulness of RS data to solve real park protection issues
- What's truly + applicable to protected area management
- Work with USGS & CCRS to routinely produce consistent, standard remote sensing data products broadly useful for ecological monitoring

b) Development of effective approaches for using RS technology

- A look to broader global application
- Approaches to monitor landscapes - pros and cons of each
- Best practices and minimum standards
- Clarifying ecological questions
- Continental best practices and standards for key vital signs
- Continental scale products
- Detection of subtle changes using higher resolution imagery

- Evaluation of methods
- Focus on interpretation and validation of key (popular metrics/ analyses.
- Follow-up on how EI monitoring guidelines were met, experiences
- Integrating continuous classifications (biophysical, invasive sp. Occurrence) w/ protocol based landcover classification and change
- Landscape pattern metrics
- Perception of the value of remote sensing & ecological management by park management
- Progress in topics (initiatives) from last meeting
- Standard assessment points/ threshold levels for various vital signs
- Status of the definition and application of assessment points and indicators
- Targets, thresholds, desired conditions
- Targets, thresholds, desired conditions
- Technological/ method developments since last meeting or updates on these efforts
- Watershed assessment of ecological condition

c) Communication

- Communication and extension
- Maybe invite more managers?
- Specific explanation to RS providers of what is needed; Specific explanation to RS providers of wish list

d) Education

- Provide education in RS to ecologists and ecological management processes to RS specialists
- Workshops to provide hands- on experience for practitioners

e) Miscellaneous

- As discussed and addressed in sessions;
- Identifying and following up on actions, so that the same meeting is not repeated
- Sustainability for NARSEC

Of those who responded, 30% would prefer the next meeting to be held in 2008, and 70% in 2009.

9. Follow-on actions

The discussions identified many actions that would advance the use of remote sensing for monitoring parks and protected areas. Actions relevant to the individual topics are listed in sections 4.3., 5.3. and 6.3., and suggestions for future activities are listed in section 8.2.. This section contains proposed actions of interest at the national (national agencies) or international (NARSEC) levels; these are consistent with, or complementary to those identified in sections 4.-8..

Among the numerous comments and suggestions, the accomplishment of certain actions requires an international and/ or interagency initiative, areas that are compatible with NARSEC focus. The main topics and possible NARSEC roles are listed below.

1- Method readiness:

- Scientific readiness/ proof of concept – key elements:
 - Peer reviewed publications

NARSEC role:

None needed (other mechanisms adequate)
- Transportability – key elements:
 - Tests – peer review approach

NARSEC role:

Facilitate cross- border tests (e.g., using other’s tools- FragCube, impervious surfaces)
- Client’s willingness to accept methods (confidence and comfort) – key elements:
 - Addressing ‘acknowledged’/ recognized problems
 - Familiarity with and confidence in results/ performance
 - Operational suitability - packaging/ user friendliness of procedures

NARSEC role:

 - Documents to articulate large area needs, drivers and impacts
 - Packages/ information aids/ documenting performance of methods and products
 - Facilitating exchange and the use of aids that enable wider application of RS products

2- Wider use of methods (in more parks and/or over larger areas):

- Needs formulation (national reporting vs. within- park management):

NARSEC role:

 - Background document(s) articulating the issues
 - Workshops, seminars (international)
- Ability to generate suitable products (implementation issue: good, cheap, reliable). Country specific but also has continental aspect:

NARSEC role:

 - Generation of continental/ cross- border products
 - Facilitating collaboration with other (continental) programs in coherent manner
- Acceptance of the products by the recipients:

NARSEC role:

- Case studies and/or example applications of products
- Informing potential users of product availability, appropriate uses, and interpretation
- Workshops, briefing docs
- Large- areas pull – national to international drivers (CC, space technology, etc.):
 - NARSEC role:
 - Address protected areas issues caused by large- area drivers
 - Promote and advise within agencies at national and international levels
 - Build on/ take advantage of international initiatives
 - Use judicious mix of tech push/ user pull

3- Regarding R&D on future methods:

- Lidar, SAR
- Use within- parks/ GPE as testing ground
- Data fusion, Models, etc.

NARSEC role:

- Articulate park agency needs to space agencies.
- Identify and communicate current studies

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11. Appendix

11.1. Agenda

North American Network for Remote Sensing Park Ecological Condition (NARSEC)

Satellite Remote Sensing for Monitoring and Reporting the Condition of National Parks

2007 Conference Agenda

March 6-8, 2007, Hotel Santa Fe, Santa Fe, New Mexico

Time	Title	Presenter	Location / Room
Day 1 – Tuesday Mar 6, 2007:			
THEME 1 - Remote Sensing for Monitoring Land Surface Change in Parks			
8:00	Registration		Kiva ballroom
8:30	Opening session	Josef Cihlar	Kiva ballroom
8:30	Objectives, meeting format, logistics	Josef Cihlar	Kiva ballroom
8:45	NPS and PCA Monitoring Programs - Use of RS and Establishment of Desired Condition for Park Landscapes	John Gross and Donald McLennan	Kiva ballroom
9:15	Theme 1 Presentations (RS for Monitoring Land Surface Change in Parks)	Donald McLennan	Kiva ballroom
9:15	Challenges in developing Landsat- based monitoring protocols in national parks	Robert Kennedy	Kiva ballroom
9:50	Land cover change protocol developed for Landsat in GRIP project	Robert Fraser	Kiva ballroom
10:15	Health Break & Poster viewing		Kiva ballroom
10:30	Land cover change in the northeastern US and its effects on natural resources	Scott Goetz	Kiva ballroom
10:55	The MRLC land cover products and advances in detecting land cover change	Collin Homer	Kiva ballroom
11:20	Status of the Landsat Data Continuity Mission	James Irons	Kiva ballroom
11:40	Key poster messages (3-5 min each)	Authors	Kiva ballroom
12:00	Lunch & Poster viewing		
13:30	Theme 1 Breakout Groups (Including Health Break)	Donald McLennan	Kiva A, B, C* Canyon Library
15:45	Breakout #1 Plenary reporting and discussion	Donald McLennan	Kiva ballroom

16:45	North American Land Change Monitoring System	Collin Homer	
17:30	Adjourn		

Time	Title	Presenter	Location / Room
Day 2 – Wednesday Mar 7, 2007:			
<i>THEME 2 - Landscape Pattern and Biodiversity in Parks</i>			
8: 00	Introduction	Woody Turner	Kiva ballroom
8:00	Evaluating landscape connectivity in an eastern US Network of parks	Todd Lookingbill	Kiva ballroom
8:25	Remote sensing based products applicable to National Park (ANP) monitoring in México	Rainer Ressler	Kiva ballroom
8:50	Pattern metrics and significance of changes in land use and cover for park resources	Dave Theobald	Kiva ballroom
9:15	FragCube: An ecologically scaled landscape index for monitoring habitat area and landscape connectivity in Canada's national parks	Paul Zorn and Justin Quirouette	Kiva ballroom
9:40	Landscape patterns and biodiversity in Mexico - new approaches to a national gap analysis	Melanie Kolb	Kiva ballroom
10:05	Health Break & Poster viewing		Kiva ballroom
10:30	State of the science for modeling focal species distributions using RS inputs	Jeremy Kerr	Kiva ballroom
10:55	Landscape-scale indicators of protected area quality and effectiveness.	Kristina Rothley	Kiva ballroom
11:20	Effects of land use and land cover change on park biodiversity	Andy Hansen	Kiva ballroom
11:45	Key poster messages (3-5 min each)	Authors	Kiva ballroom
12:00	Lunch & Poster viewing		
13:30	Theme 2 Breakout Groups (Including Health Break)	Woody Turner	Kiva A, B, C* Canyon Library
16:00	Breakout #2 Plenary reporting and discussion	Woody Turner	Kiva ballroom
17:00	Cash bar		

Time	Title	Presenter	Location / Room
Day 3 – Thursday Mar 8, 2007			
THEME 3 – Desired Conditions for Protected Landscapes - Setting Targets and Thresholds			
8:00	Introduction	John Gross	Kiva ballroom

8:05	Landscape-scale thresholds and desired conditions for parks: synthesis of break out groups and an example from Parks Canada.	Donald McLennan, Paul Zorn, John Gross	Kiva ballroom
8:50	Plenary discussion	Steering Committee	Kiva ballroom
10:30	Health Break		Kiva ballroom
10:50	Workshop summary and follow-on actions	John Gross, Donald McLennan	Kiva ballroom
11:45	Closing comments	Donald McLennan and John Gross	Kiva ballroom
12:00	Adjourn		

11.2. Charge to breakout discussion groups

Approach

- Each Participant to select the group of most interest to him/her
- Moderators and Rapporteurs to guide discussions in a consistent manner
- Highlights of discussions to be presented to the plenary
- Records of discussions to be used in preparing the meeting report

Breakout #1 Discussion: RS for Monitoring Land Surface Change in Parks

BG#1A: Readiness and Applicability of the Land Surface Methods (presented in plenary)

1. Readiness of methods: Which of the presented methods are ready for ongoing use? What are particular strengths and weaknesses of the various approaches, and could hybrid methods be more desirable? Has accuracy (levels achieved, assessment method, communication) been addressed satisfactorily? Are the needs for independent reference data realistic? What further R&D work is considered essential or highly desirable?
2. Use of methods: For methods that are ready for wider use, what would be the most effective approach to extend their use to other national parks (up to N.A. continent if appropriate)? To which ecoregions should the individual methods be expended? Are standards/ protocols necessary, which ones exist already, and how should additional ones be developed? How can/should the RS- based measures or products be used in establishing targets, thresholds and desired condition? How can/ should they be used for communicating park issues to the target audiences (e.g., are different forms of the products required)?
3. Actions: With reference to the topics discussed by the BG#1, what priority actions should be taken to ensure ongoing use (by method as appropriate; not more than 5-7 action items; consider making use of national or other initiatives)?

BG#1B: Other Highly Promising RS-based Methods and Needs in Land Surface Monitoring

1. What other mature methods exist that are being applied or might be applied to monitoring land surface change in parks? For each method, identify:
 - a) The application/ information provided (actual, project/location; or potential)
 - b) Key strengths and limitations
 - c) Reference(s)/ sources of more detailed information
2. What other types of important information about parks (other than those presented in the plenary) might be obtained from satellite- based RS data e.g., land cover change, disturbances, land use change, phenology, vegetation characteristics such as LAI and crown closure, roads)? Identify a 'short list' where (based on present knowledge) important information requirement can be matched with existing or planned sensors (time horizon = 5 years). For each case:
 - a) Define clearly the need to be met and why it is important
 - b) Describe the performance requirements that a RS- based method should meet, including minimum requirements (level below which RS would make no useful contribution); and identify other relevant expectations
 - c) Identify and characterize scientific or technical challenges to be overcome
 - d) Propose specific actions to be taken for that case
2. For methods and approaches in questions 1 and 2: Identify priority actions that should be considered by i) park agencies, ii) satellite agencies, and iii) the scientific community (with respect to topics discussed by BG#2; consider making use of national or other initiatives).

BG#1C: Barriers to Use of RS- based Methods and Products

1. What are the main barriers (consider technical, organizational, resources, cultural)? For each address:
 - a. What specifically is the issue (define it clearly)?
 - b. Can they be removed and how?
 - c. If not, can it be mitigated and how?
 - d. What specific actions should be taken and by whom - depending on what constructive role(s) they may play, consider some or all of the following target groups: park staff, park managers, national park agency, national earth observation agency, the scientific community, the public?
2. What priority actions should be taken to significantly enhance the ongoing use of RS- based products and methods in national parks (prioritized, and no more than 5 for each target group; consider making use of national or other initiatives)?

Breakout #2 Discussion: Landscape Pattern and Biodiversity in Parks

BG#2A: Landscape Patterns

1. Which of the presented methods are ready for ongoing use? What are particular strengths and weaknesses of the various approaches, and could hybrid methods be more desirable? What further R&D work is considered essential or highly desirable (by method if applicable)?

2. What other types of important information on landscape pattern (other than those presented in the plenary) might be obtained from satellite- based RS data? Identify a 'short list' where (based on present knowledge) important information requirement can be matched with existing or planned sensors (time horizon = 5 years). For each case:
 - a) Define the need to be satisfied
 - b) Describe the performance requirements that a RS- based method should meet, and identify other relevant expectations
 - c) Identify and characterize scientific or technical challenges to be overcome
 - d) Propose specific actions to be taken for that case
3. How can/should the RS- based measures or products be used in establishing targets, thresholds and desired condition (e.g., how should landscape indices be selected and produced)? How can/ should the RS- based measures be used for communicating park issues to the target audiences (e.g., are different forms of the products required)?
4. With reference to the topics discussed by this BG, what actions (prioritized) should be taken to ensure ongoing use (by method as appropriate, not more than 5-7 action items; consider making use of national or other initiatives)?

BG#2B: Biodiversity

1. Which of the presented methods are ready for ongoing use? What are particular strengths and weaknesses of the various approaches, and could hybrid methods be more desirable?
2. What other approaches should be explored to make effective use of RS- based data and methods for biodiversity purposes?
3. What further R&D work is considered essential or highly desirable (by method if applicable)?
4. Identify and prioritize actions for each of i) individual national parks, b) national park agencies, c) satellite agencies, and iv) the scientific community that should be taken to advance the use of RS techniques for biodiversity (also consider making use of national and tri-national initiatives).

Theme 3 Plenary Discussion: Desired Conditions for Protected Landscapes - Setting Targets and Thresholds

1. What are the most promising approaches to defining specific, landscape-scale desired condition? Which of the metrics presented can lead to defensible, quantitative assessment points relevant to management?
2. What role(s) can RS- based technology play? How can the RS based measures of landscape change be converted into indicators of ecological integrity that have measurement scales, thresholds and targets?
3. How can the parks management structure (local to national) ensure/ support effective use of RS technology in this area?
4. What are the most promising near-future opportunities to develop/ test such approaches at local to regional scales (also consider making use of national and tri-national initiatives)?

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